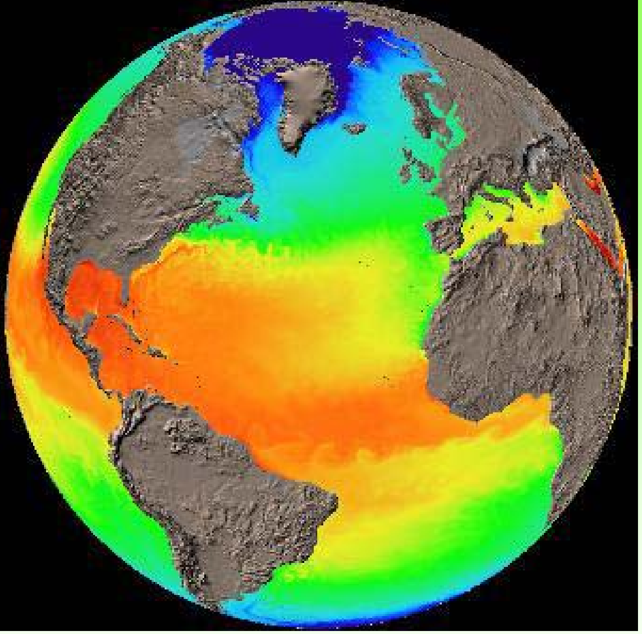
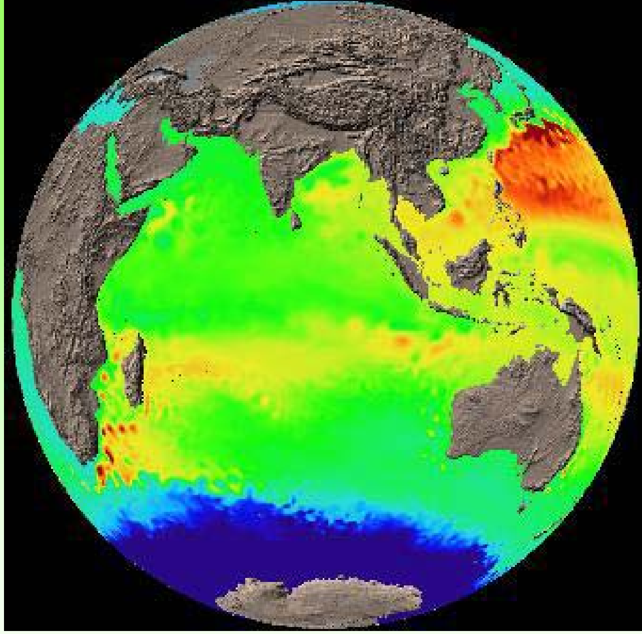


Towards a Global Coupled Navy Prediction System: The Ocean Component



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Users Group Conference 2002

Austin Texas, 10-14 June, 2002

Collaborators and Acknowledgements

- Team Members: D. Ivanova, P. Thoppil (all NPS), and C. Priewe (NPS/Moss Landing Marine Labs).
- Collaborators/Co-Is: F. Bryan (NCAR), C.S. Chiu (NPS), A. Semtner (NPS), R.Smith (LANL), R. Tokmakian (NPS).
- Visualization: NAVO MSRC (Gruzinskas, Haas, Goon), ACL (LANL), and D. Ivanova (NPS)
- Computer Resources: DOD HPCMO: NAVO, ARSC, ARL. ACL @LANL.
- Data: AOML, JEDA,WOCE DACs, U of H, BODC
- Funding: ONR, DOE/CCPP, NSF.

Navy Prediction Vision

- A high-resolution global coupled air/ocean/ice prediction system.

- Very-high resolution regional coupled models nested into the global system at strategic locations.

Objectives

- Perform a two-decade spin-up of a high-resolution global configuration of POP.
- Perform a decade-long integration for the 1990's using high-frequency NOGAPS surface forcing up to as close to real time as possible.

- Provide a realistic, high resolution global ocean state for:
  - Data assimilation and forecasting
  - Coupling with the ice and atmospheric models.
  - Lateral boundary conditions for regional models.
  - Realistic turbulence statistics for sub-grid eddy parameterizations
  - Ocean process studies
  - Push limits of state-of-the-art high performance computers

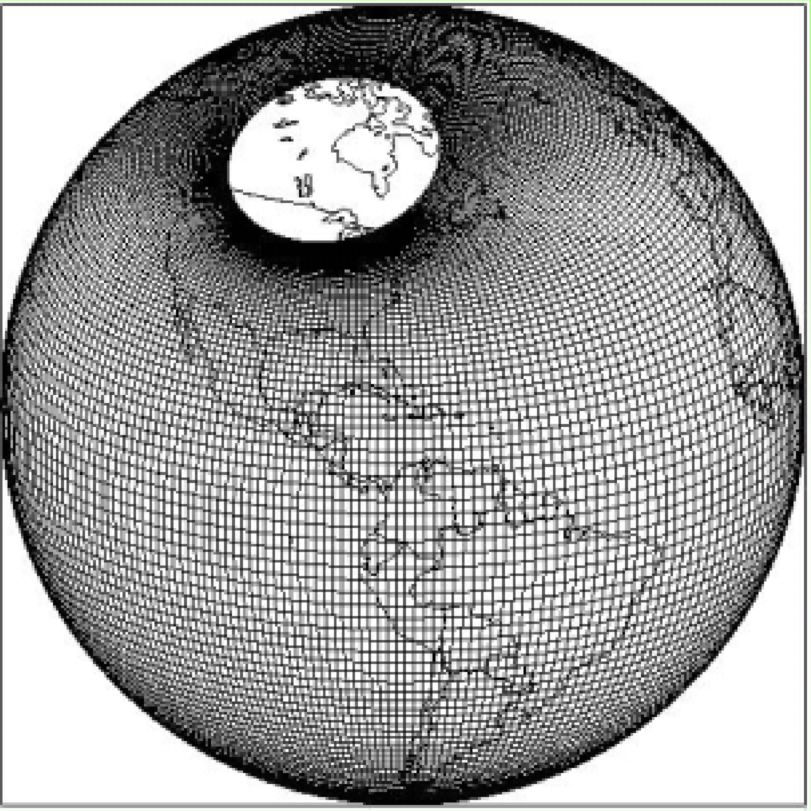
Approach:

Description of 0.1°, 40-level Global POP Spin-Up

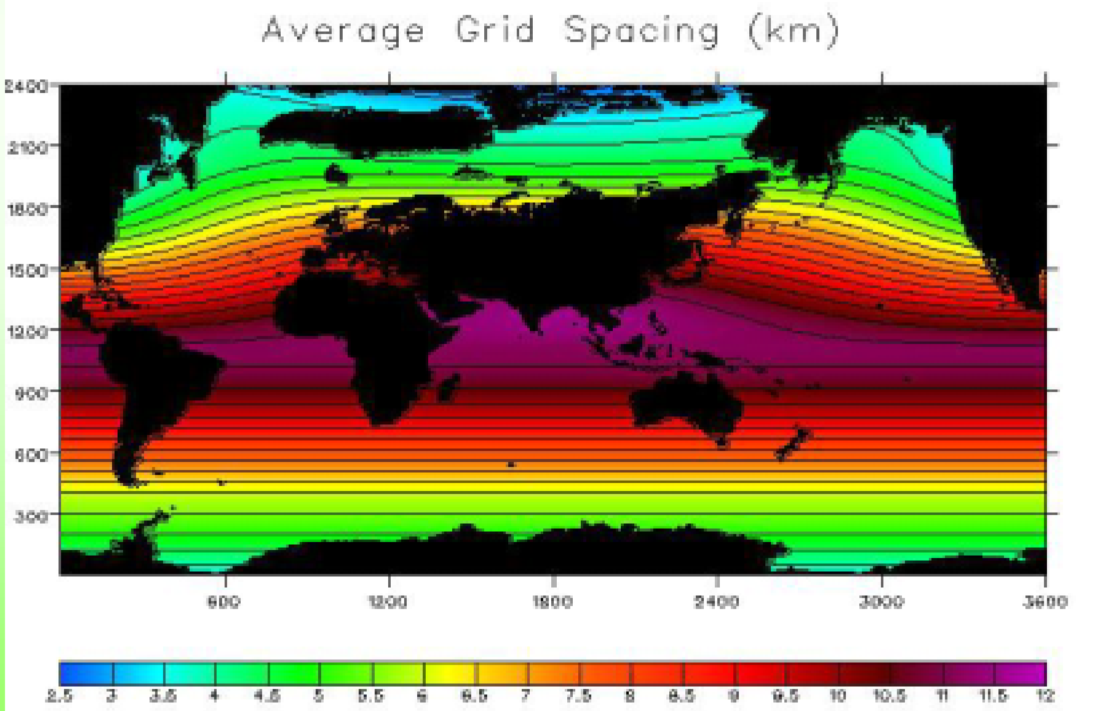
- Fully global displaced North Pole grid (includes Arctic)
- 3600x2400x40 grid points
- POP release 1.3
- ``Natural'' spin-up from rest: Initialized from blended 1/8° MODAS (January) and POLES (winter) PT and S (Piacsek)
- Topography: Sandwell and Smith (71S-67N), IBCAO (66N-90N), & BEDMAP (66S-79S). Modifications to encourage more realistic flow.
- Synoptic surface forcing from 01/79-12/98.
- KPP mixed layer
- Biharmonic mixing, 6.3 min. time step
- Source code: http://climate.acl.lanl.gov
- IBM SP3 @ NAVO: 500 procs. -44 model days/wallclock days
- Evaluate boundary currents, transports, overflows, water mass characteristics, energy levels.

http://www.oc.nps.navy.mil/navypop

Fully Global Displaced North Pole Grid



Pole is rotated into Hudson Bay to avoid polar singularity. Highest horizontal resolution off east and west coasts of the U.S

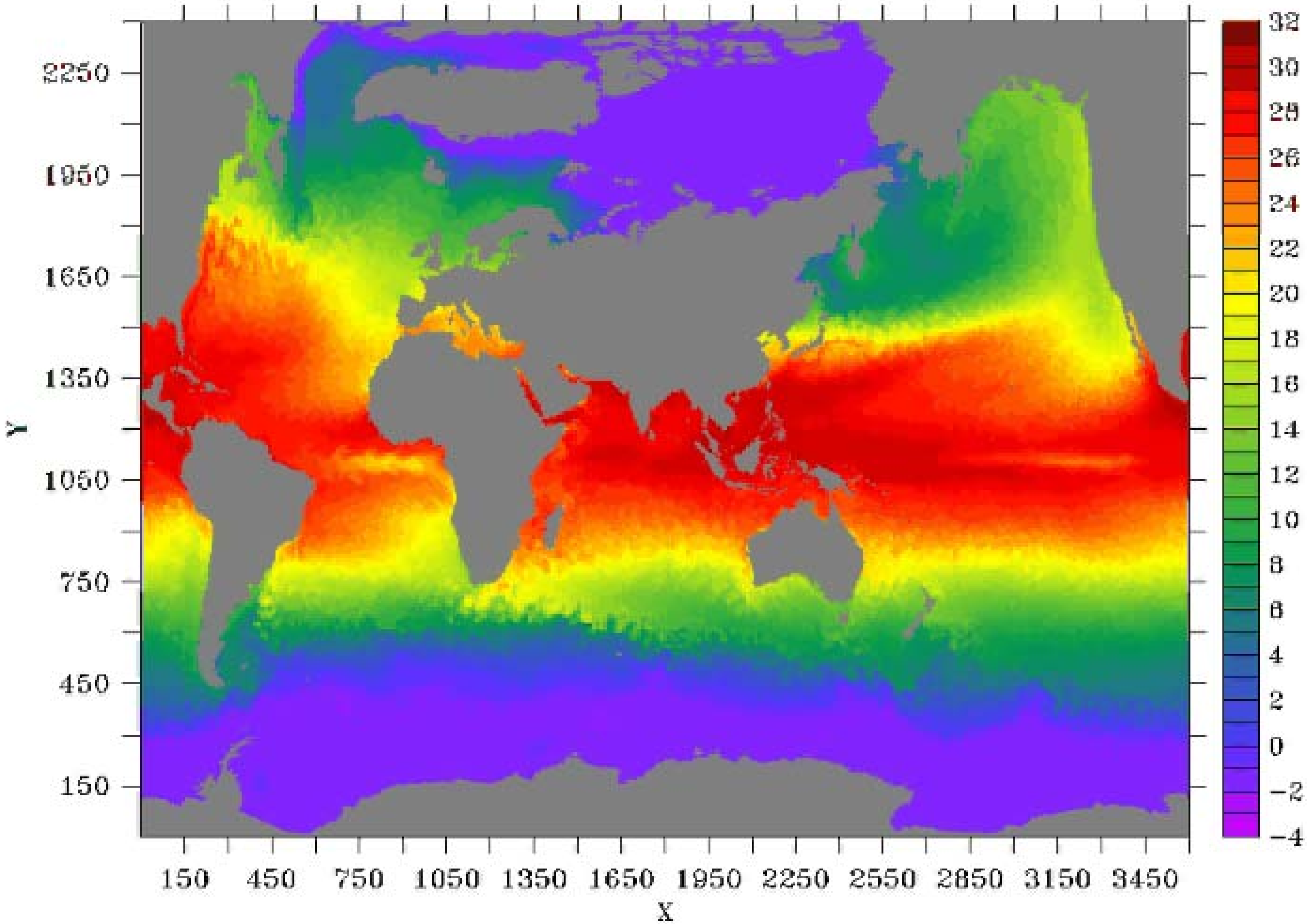


Average grid spacing is 12 km to 2.5 km

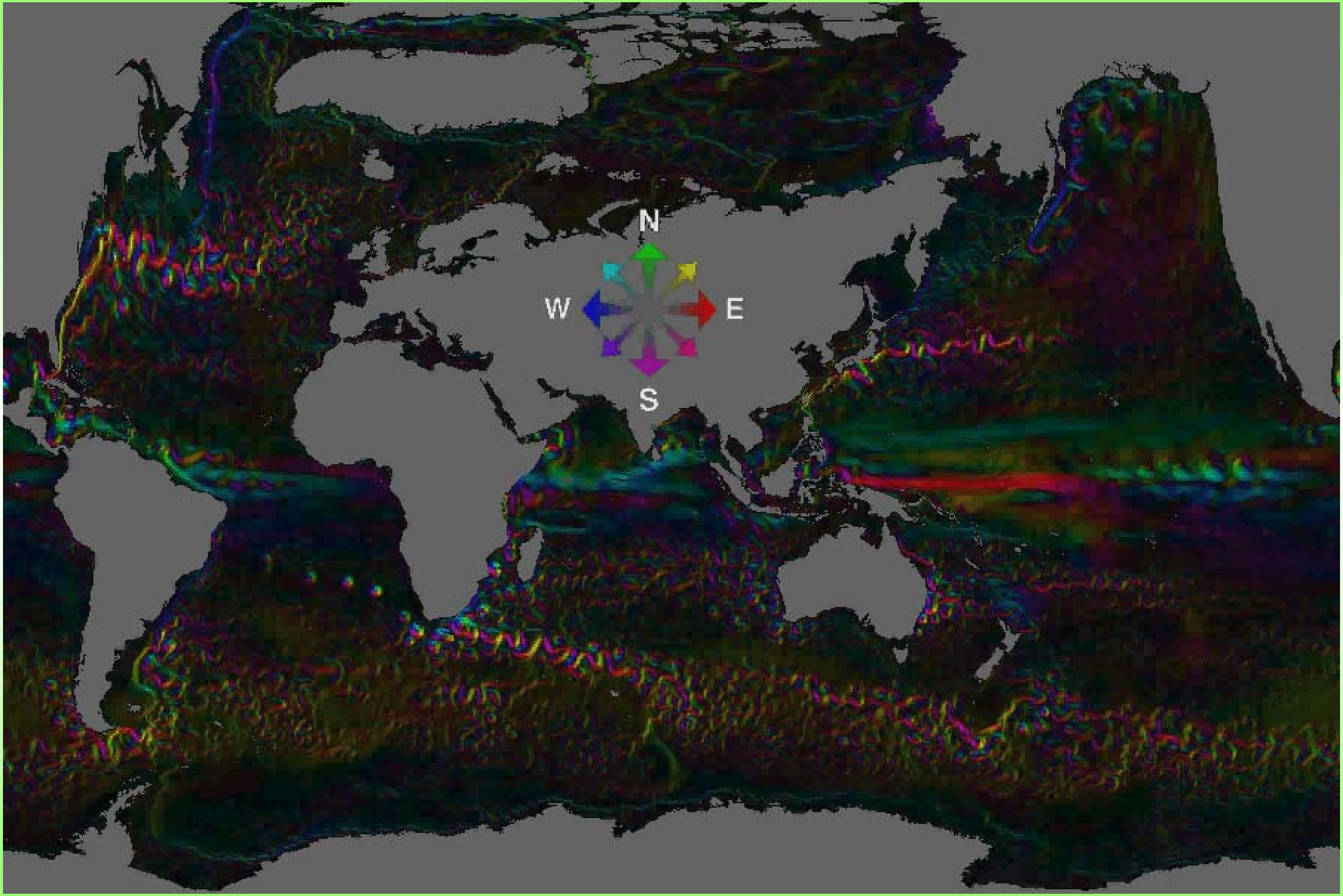
Why such a resource-intensive global ocean model?

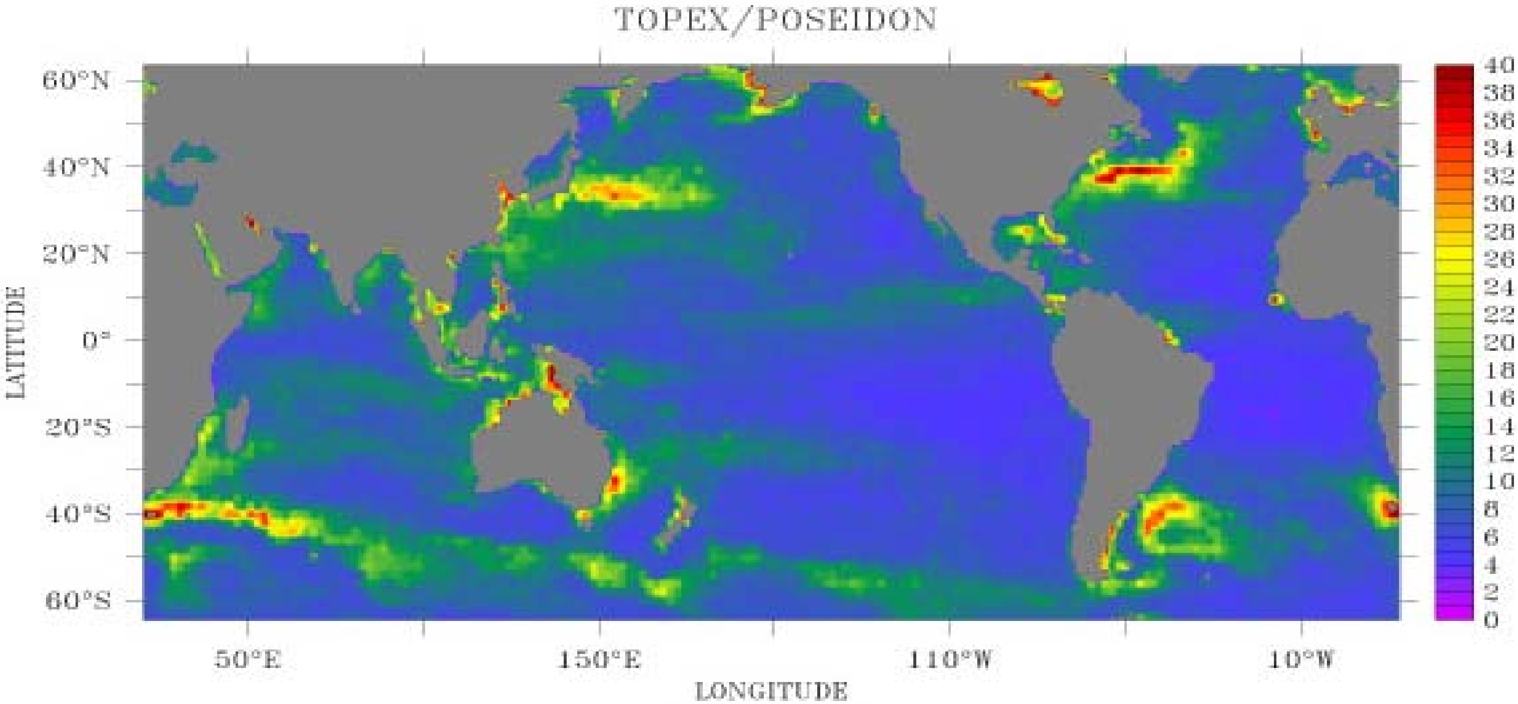
- Ocean model must be capable of simulating high-frequency (days to several months) and short-scale processes (10-1000 km). Particularly, the mean and varying surface/thermocline flows and thermohaline structure of upper-ocean.

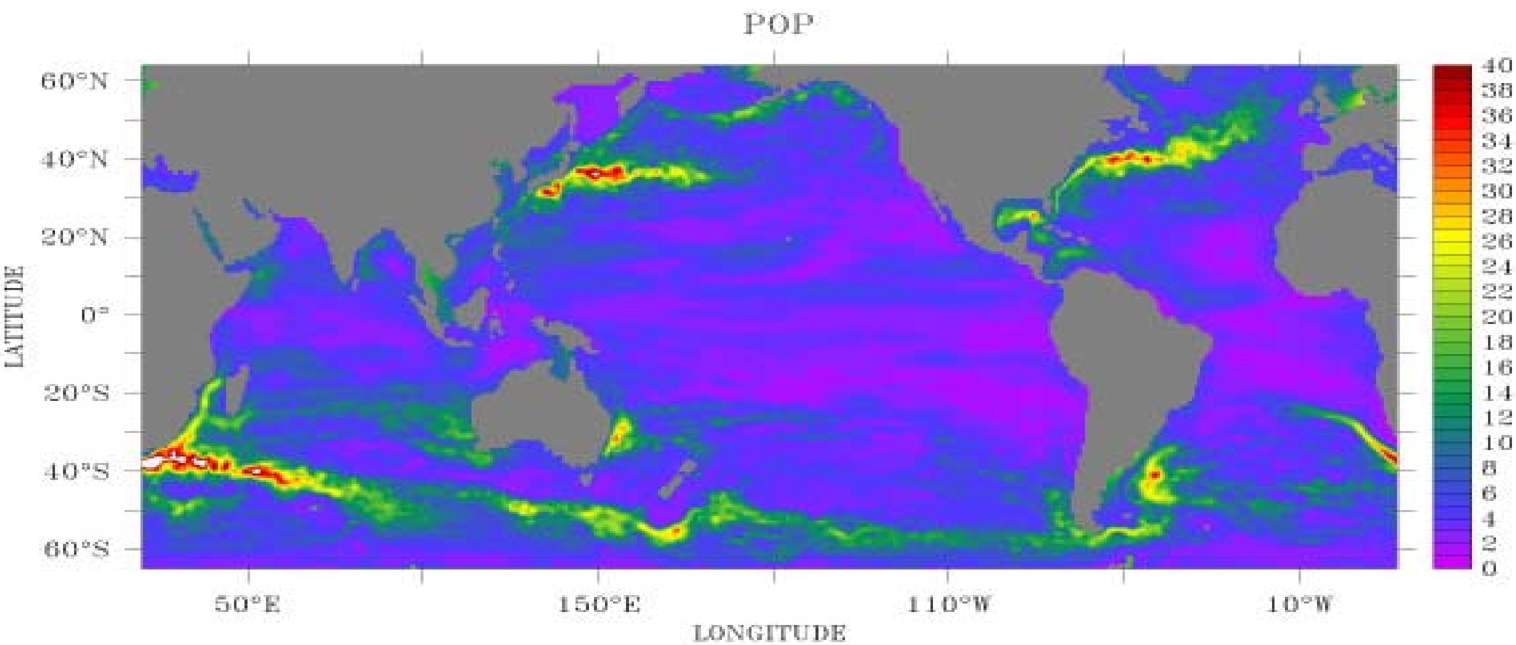
- High vertical and horizontal resolution are required to produce mesoscale variability and strong, narrow mean currents such as the Gulf Stream.



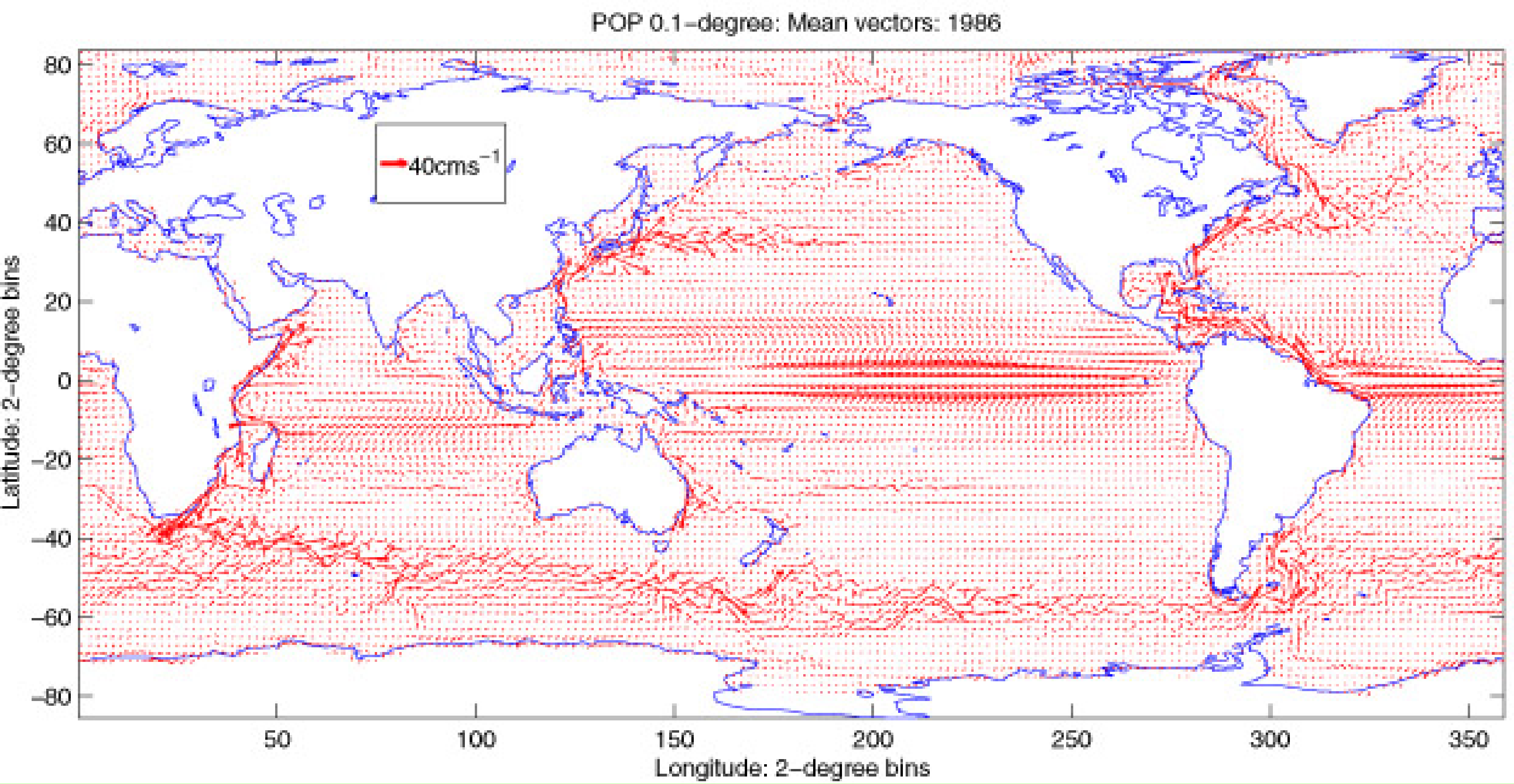
SST (°C), 07/1983−07/1984


N
W
E
S

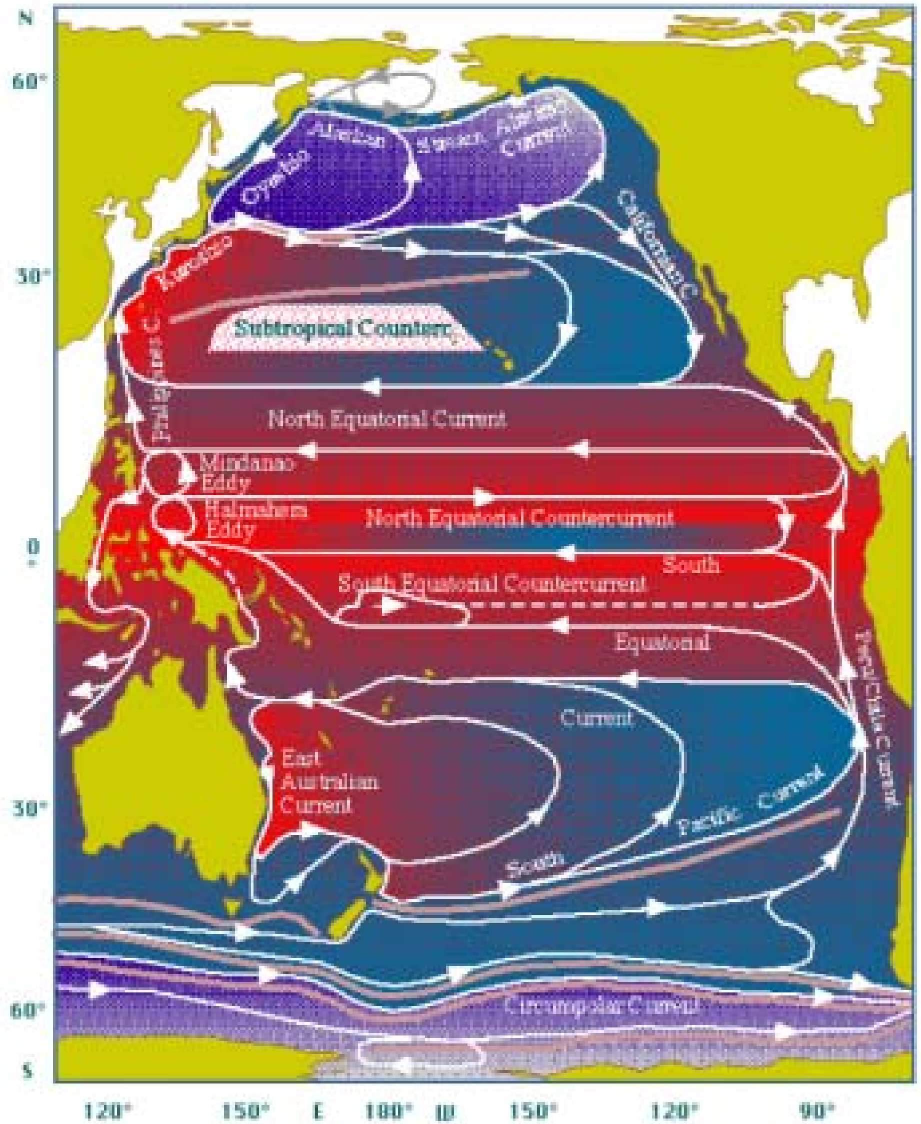

TOPEX/POSEIDON
60°N
40°N
20°N
0°
20°S
40°S
60°S
LATITUDE
50°E
150°E
110°W
10°W
LONGITUDE
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0


POP
60°N
40°N
20°N
0°
20°S
40°S
60°S
LATITUDE
50°E
150°E
110°W
10°W
LONGITUDE
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0

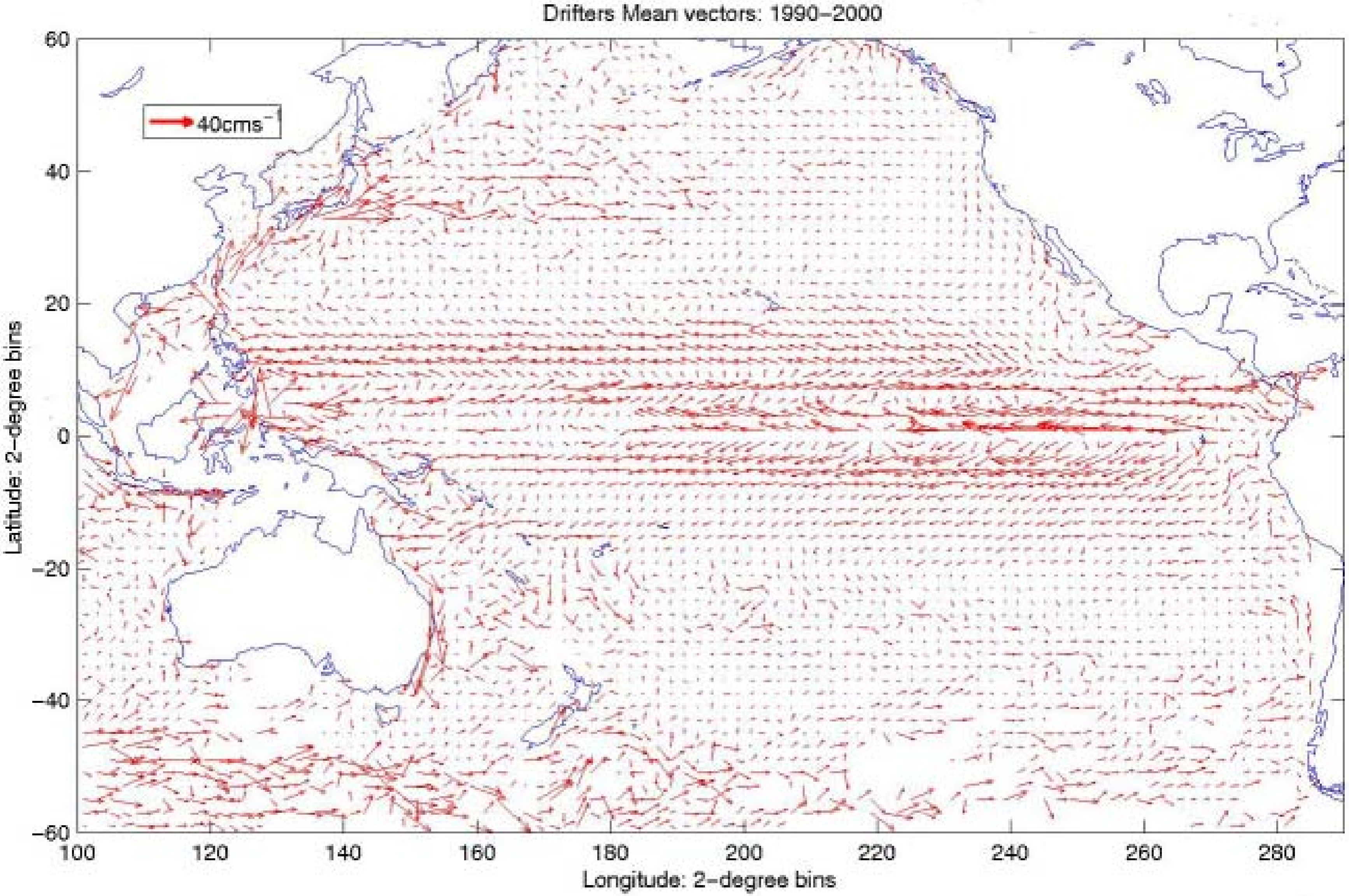
RMS SSH (cm)

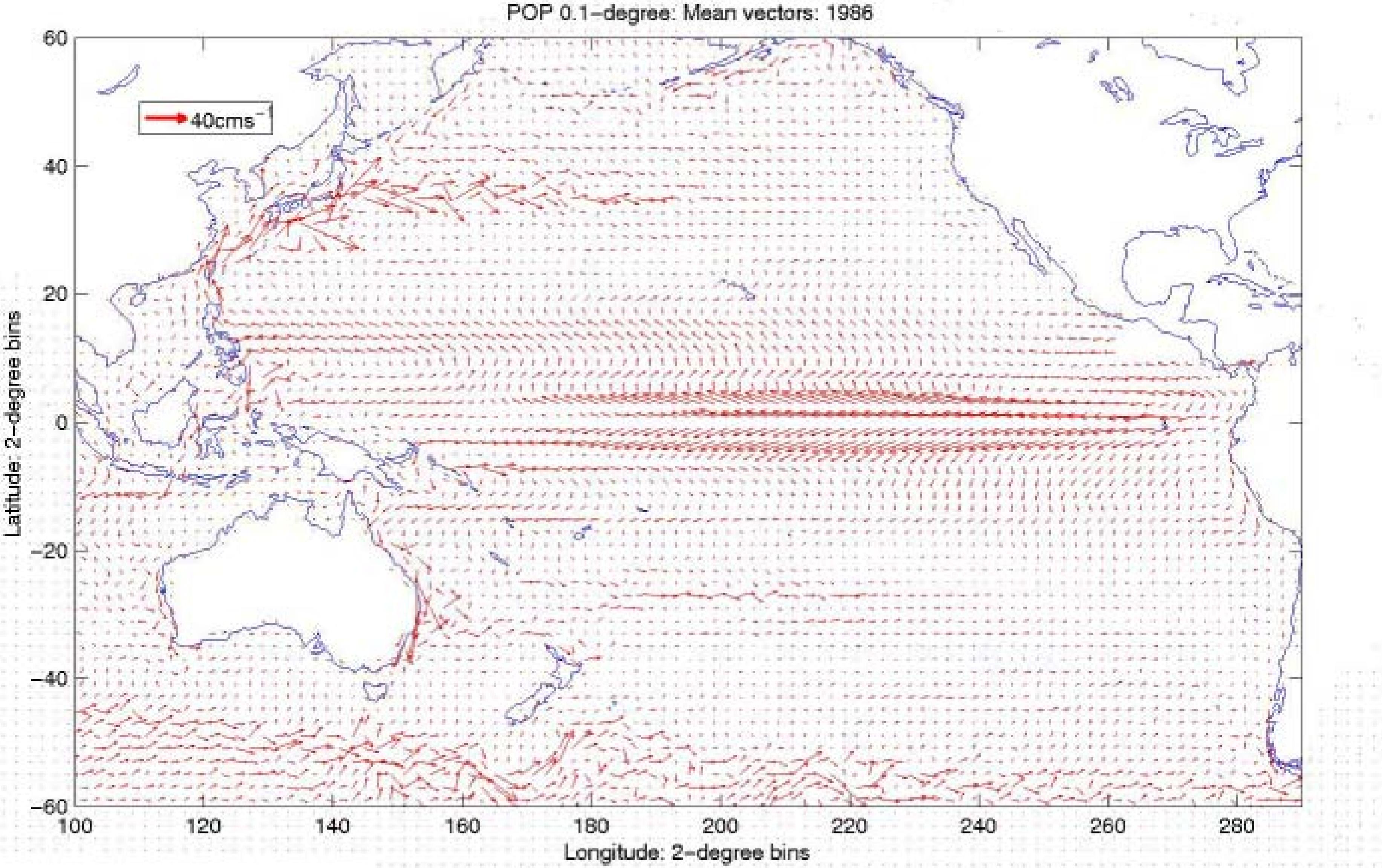

POP 0.1-degree: Mean vectors: 1986
40cms^-1
Latitude: 2-degree bins
Longitude: 2-degree bins
80
60
40
20
0
-20
-40
-60
-80
50
100
150
200
250
300
350

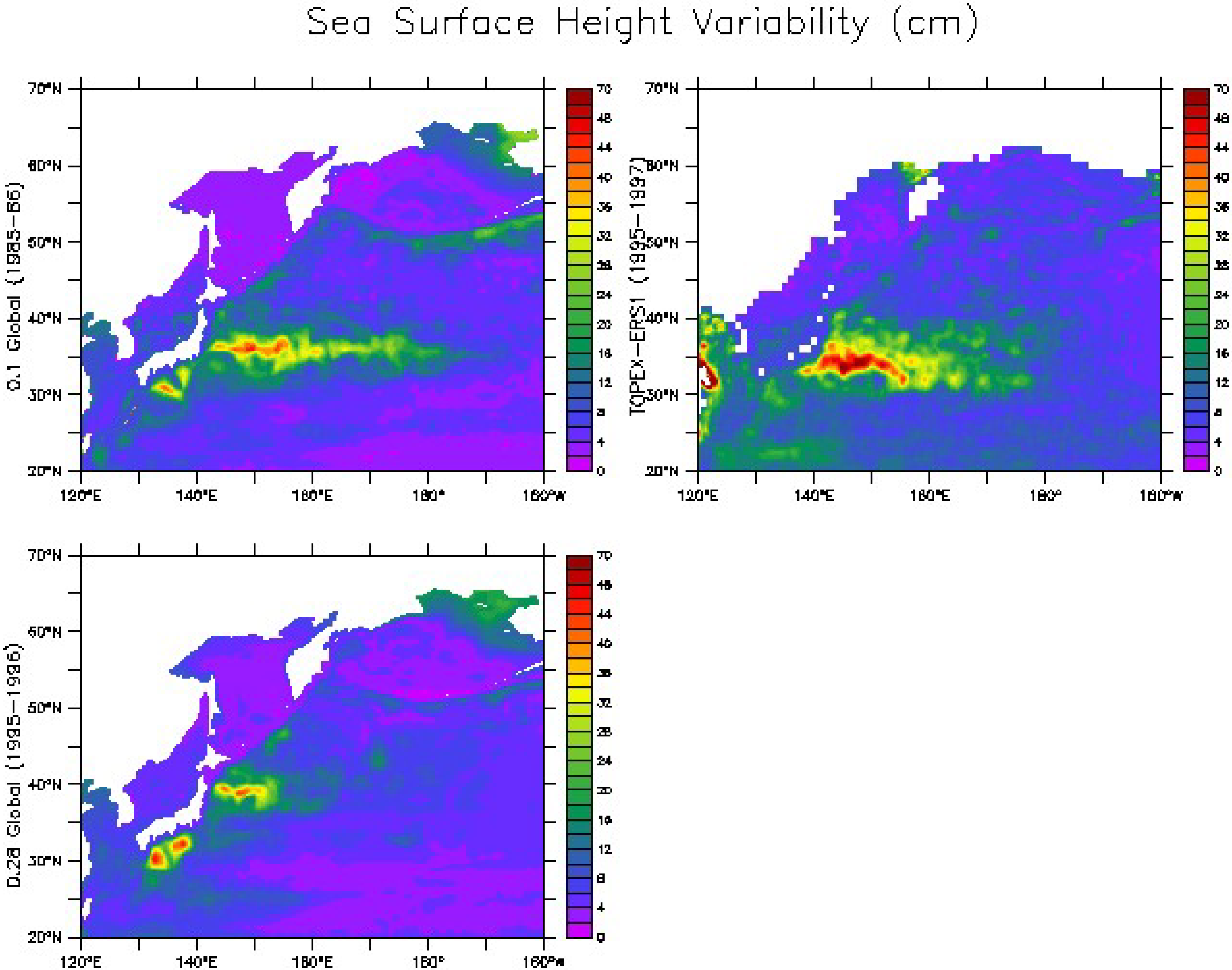
Pacific Ocean

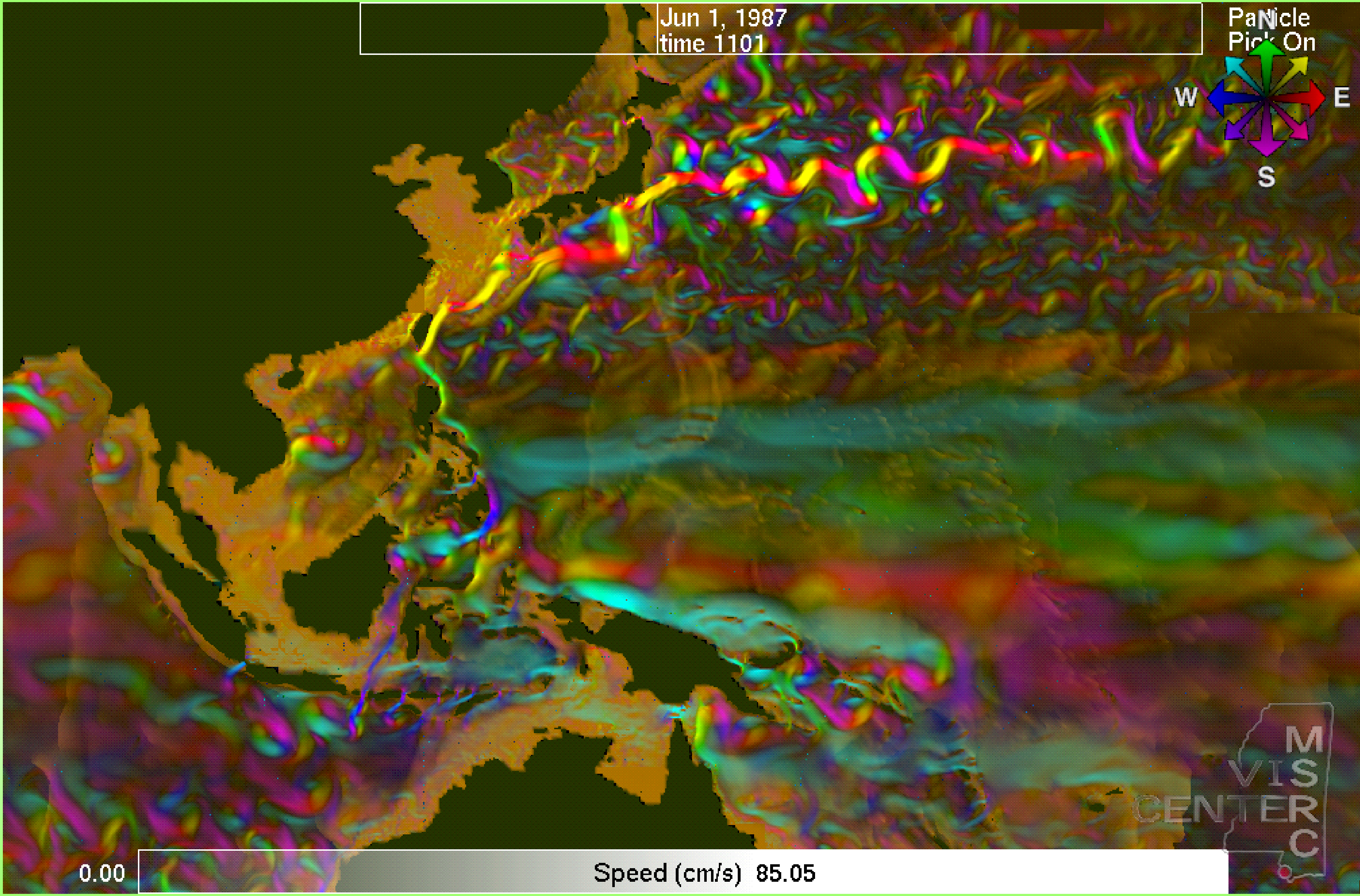


This is a colour version of Figure 8.6 of **Regional Oceanography: an Introduction** by M. Tomczak and S. J. Godfrey (Pergamon Press, New York 1994, 422 p.). See chapter 8 of the textbook for more detail on what is shown in this figure.

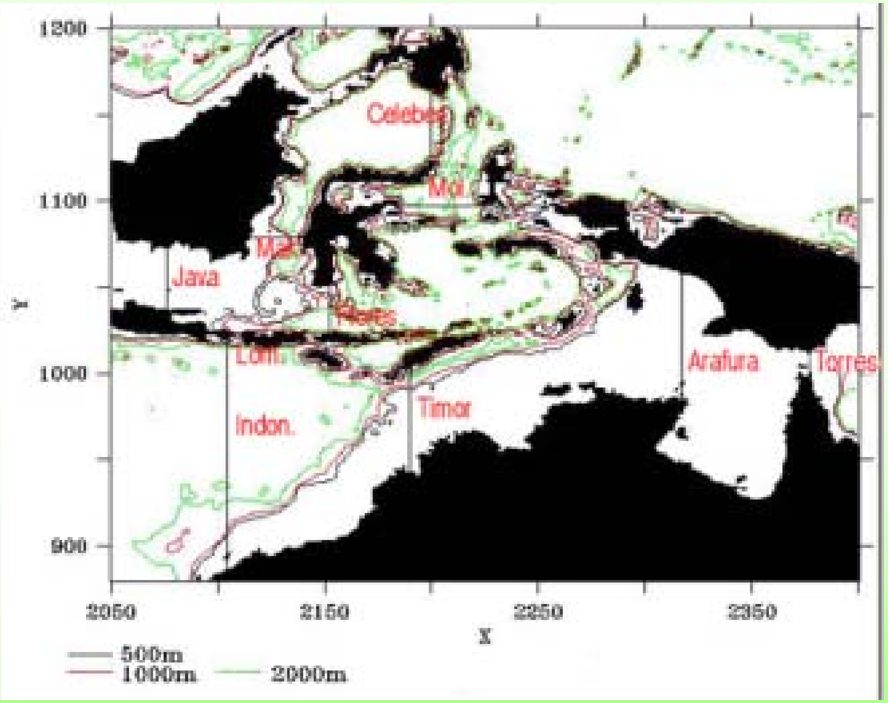

Drifters Mean vectors: 1990–2000
40cms⁻¹
Latitude: 2–degree bins
Longitude: 2–degree bins
60
40
20
0
−20
−40
−60
100
120
140
160
180
200
220
240
260
280

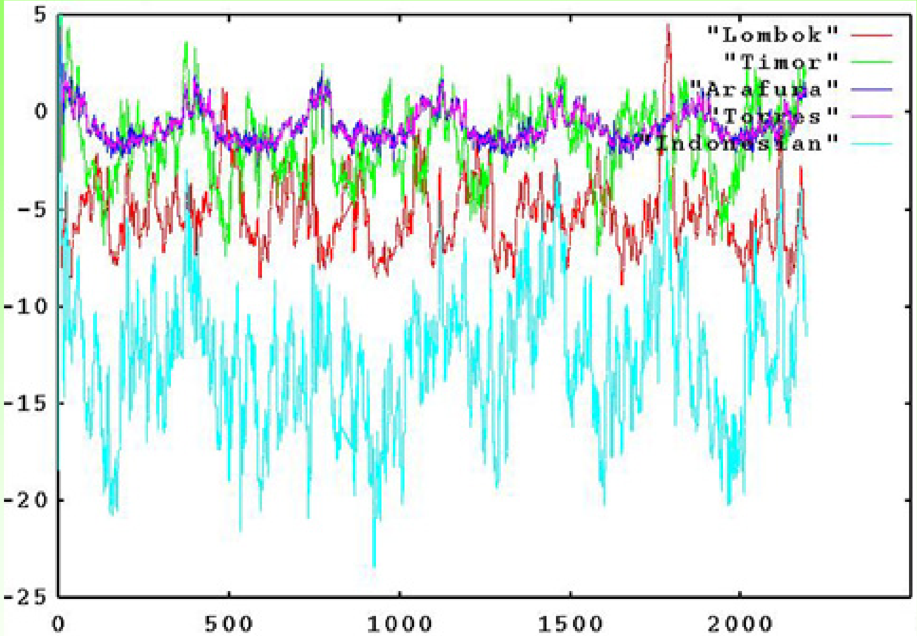

POP 0.1-degree: Mean vectors: 1986
40cms^{-1}
Latitude: 2-degree bins
Longitude: 2-degree bins
60
40
20
0
−20
−40
−60
100
120
140
160
180
200
220
240
260
280

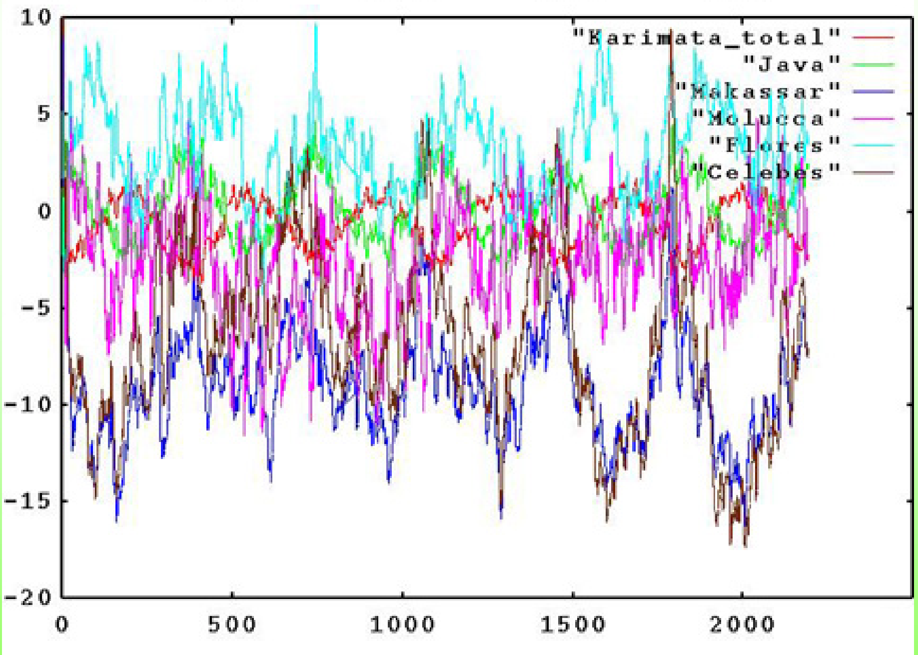

Sea Surface Height Variability (cm)
0.1 Global (1995-96)
TOPEX-ERS1 (1995-1997)
0.28 Global (1995-1996)
70°N
60°N
50°N
40°N
30°N
20°N
120°E
140°E
160°E
180°
160°W
0
4
8
12
16
20
24
28
32
36
40
44
48
70


Jun 1, 1987
time 1101
Particle
Pick On
N
W
E
S
0.00
Speed (cm/s) 85.05
MS
VIS
CENTER
C

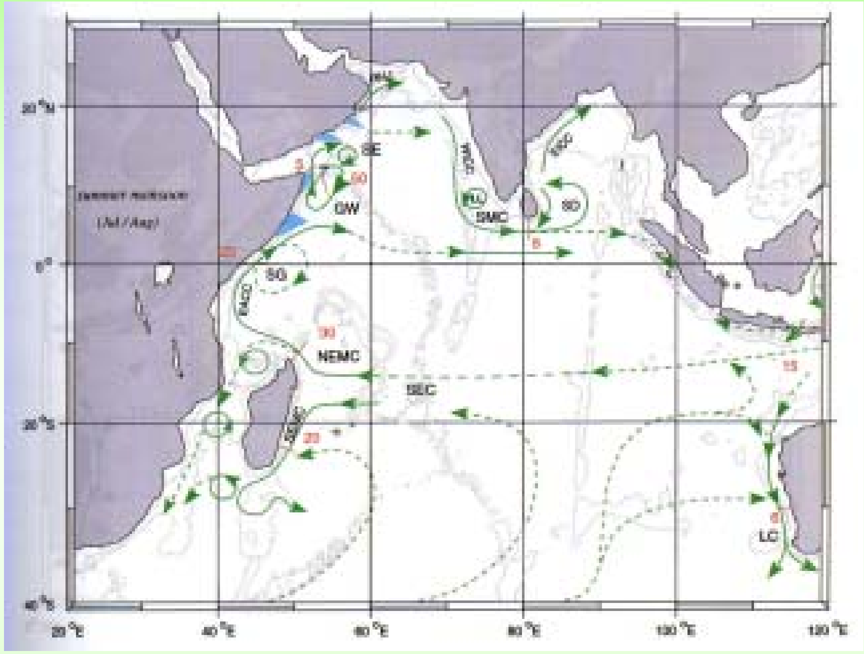
Mass Transports (Sv) through the Indonesian Seas for the first 6 years of the spin-up.



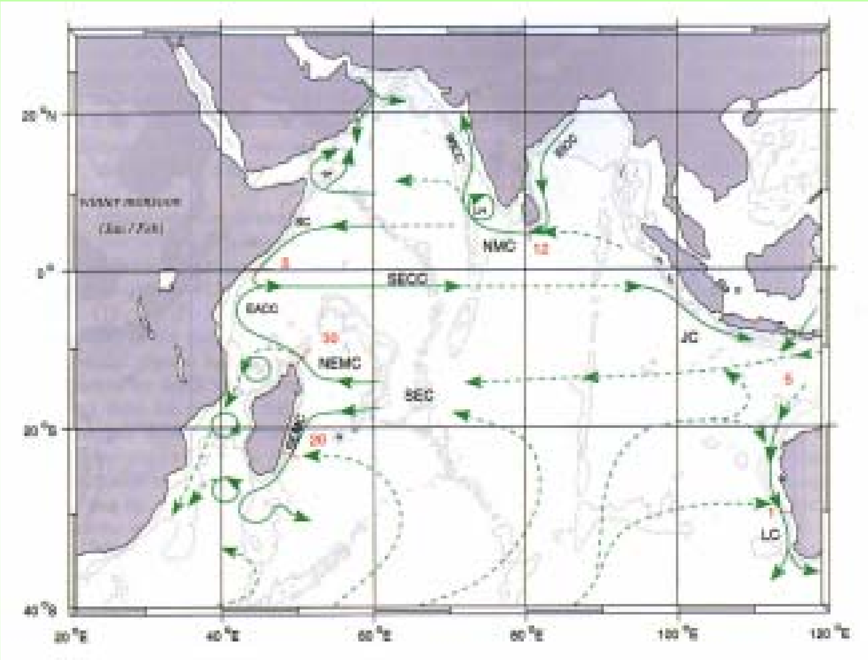




Southwest Monsoon



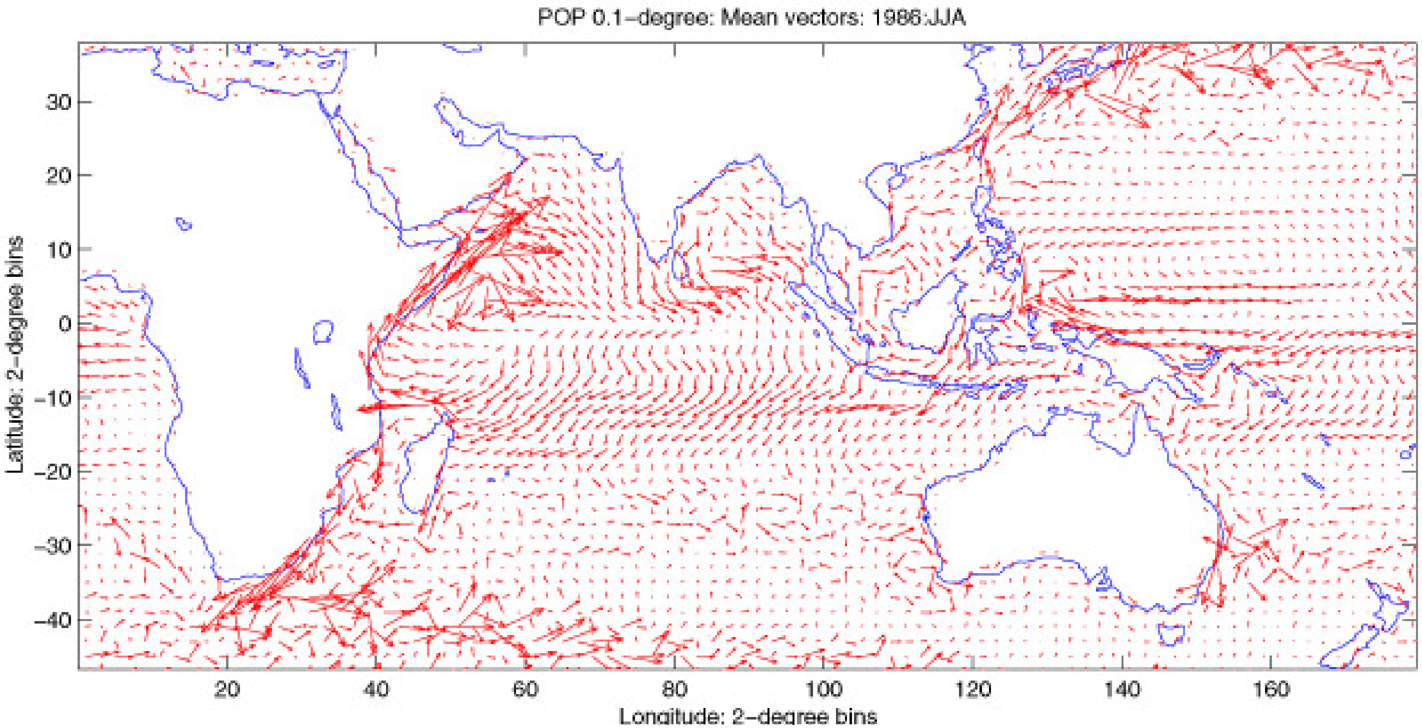
Northeast Monsoon



Schott and McCreary, 2001

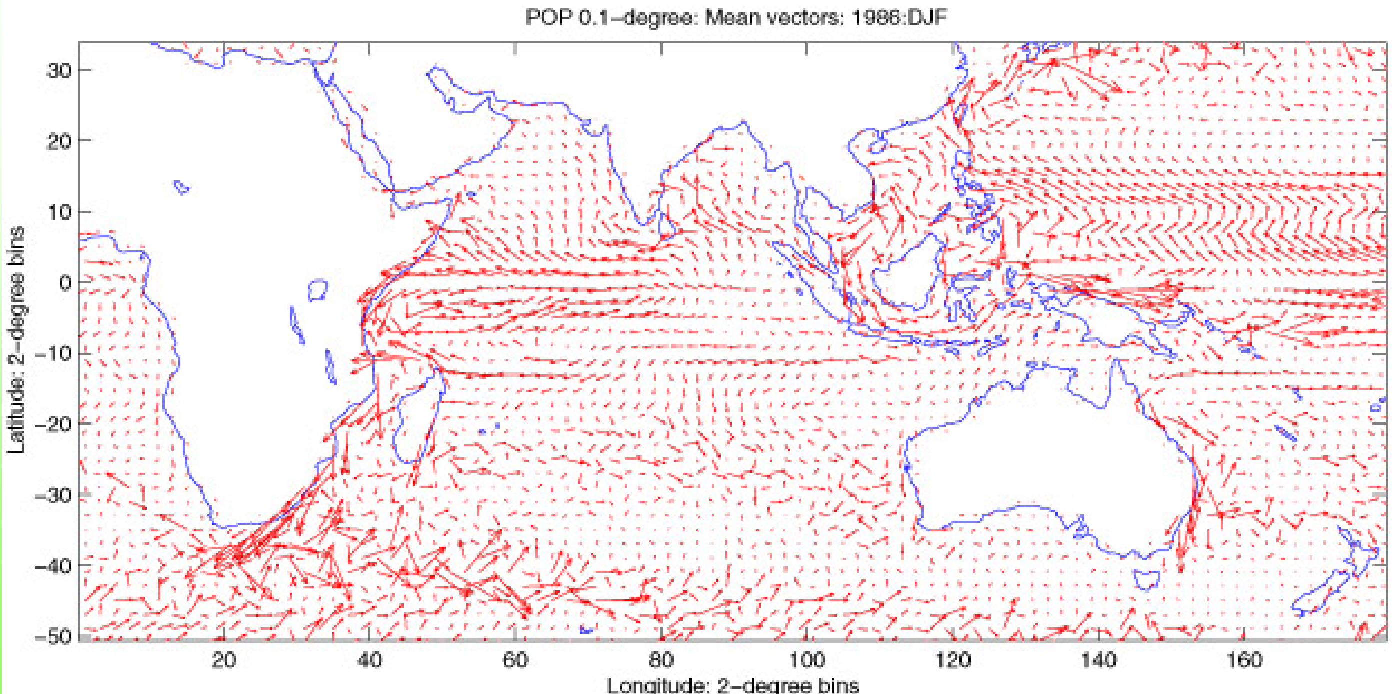
Boreal

Summer

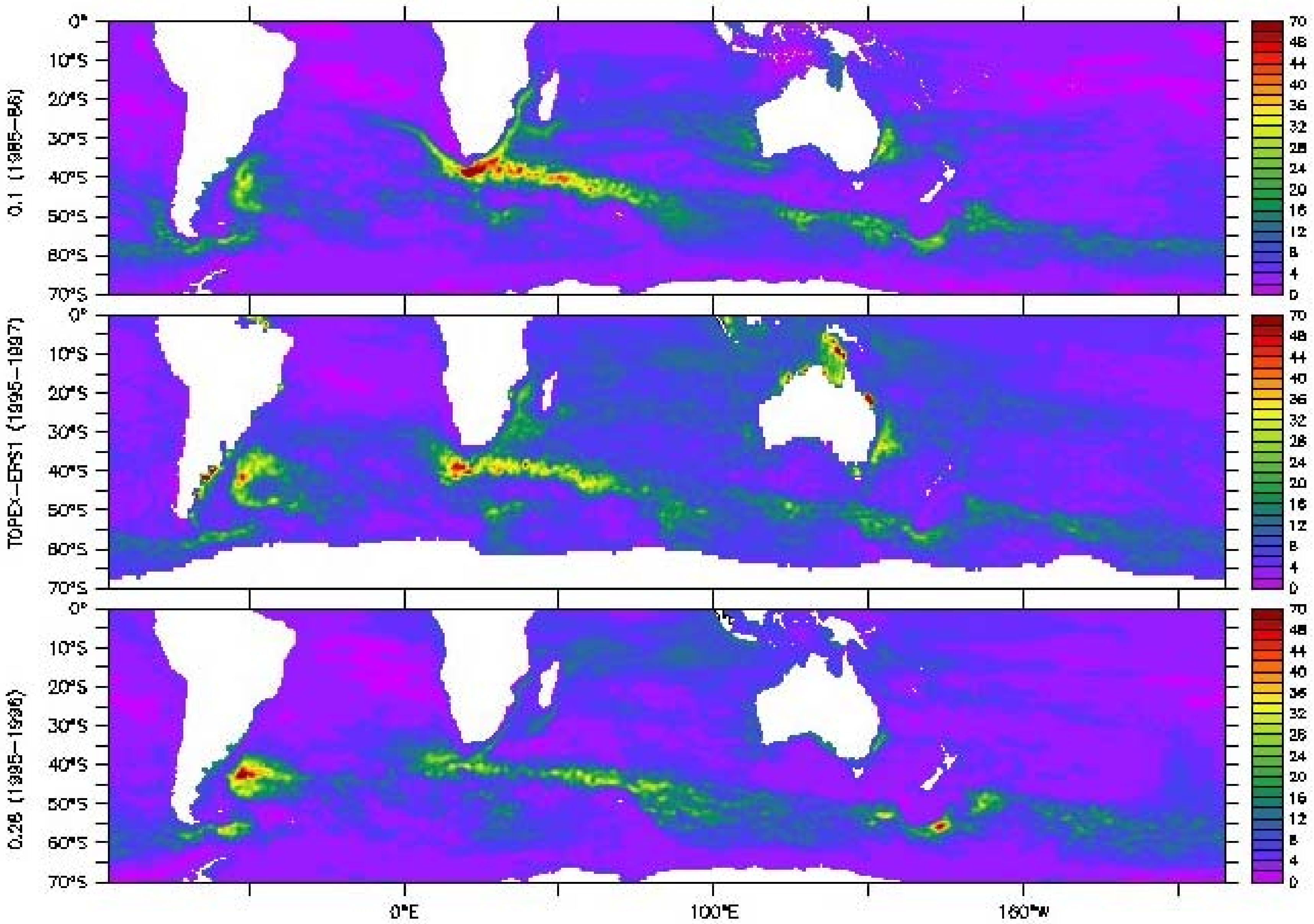


Boreal

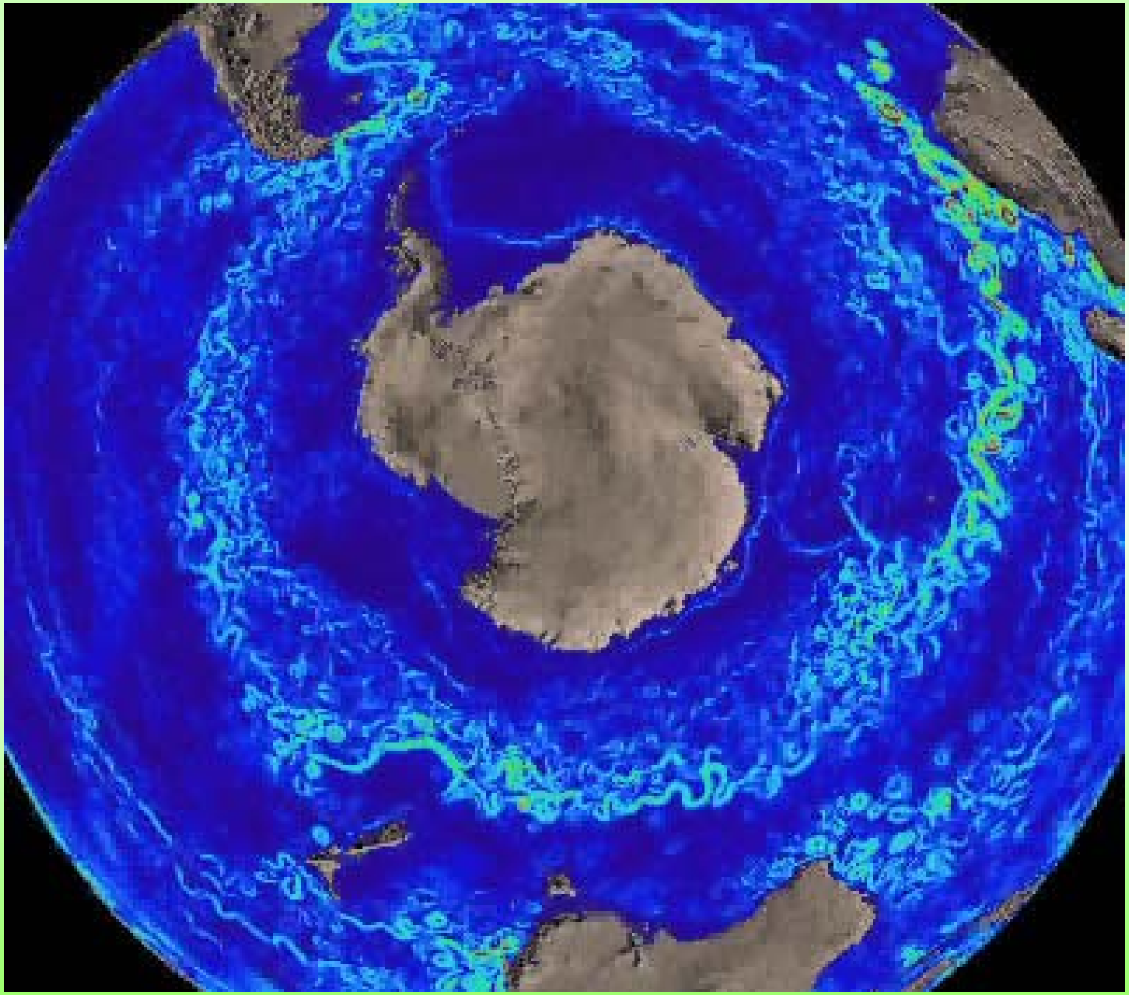
Winter



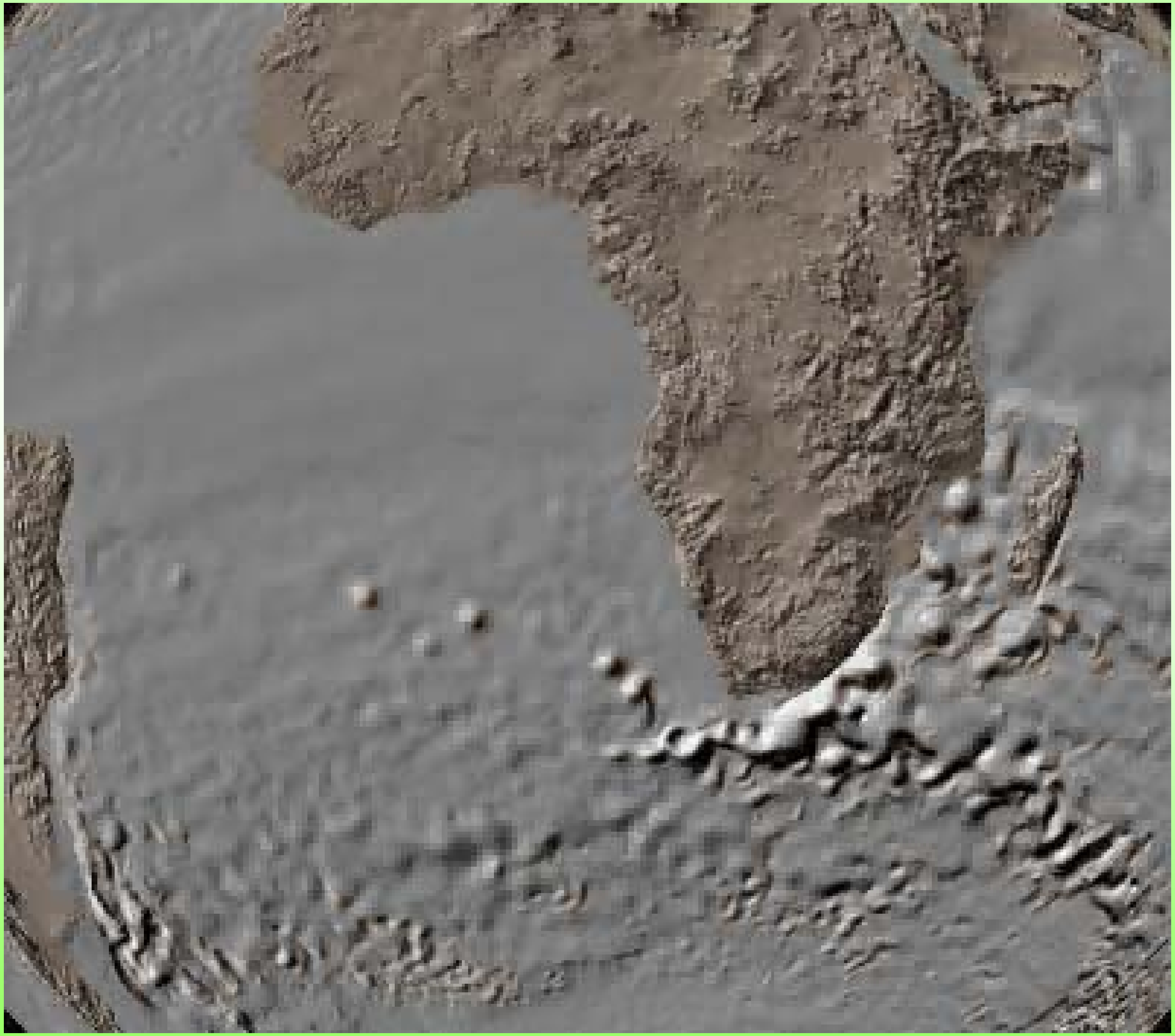
Sea surface height variability (cm)



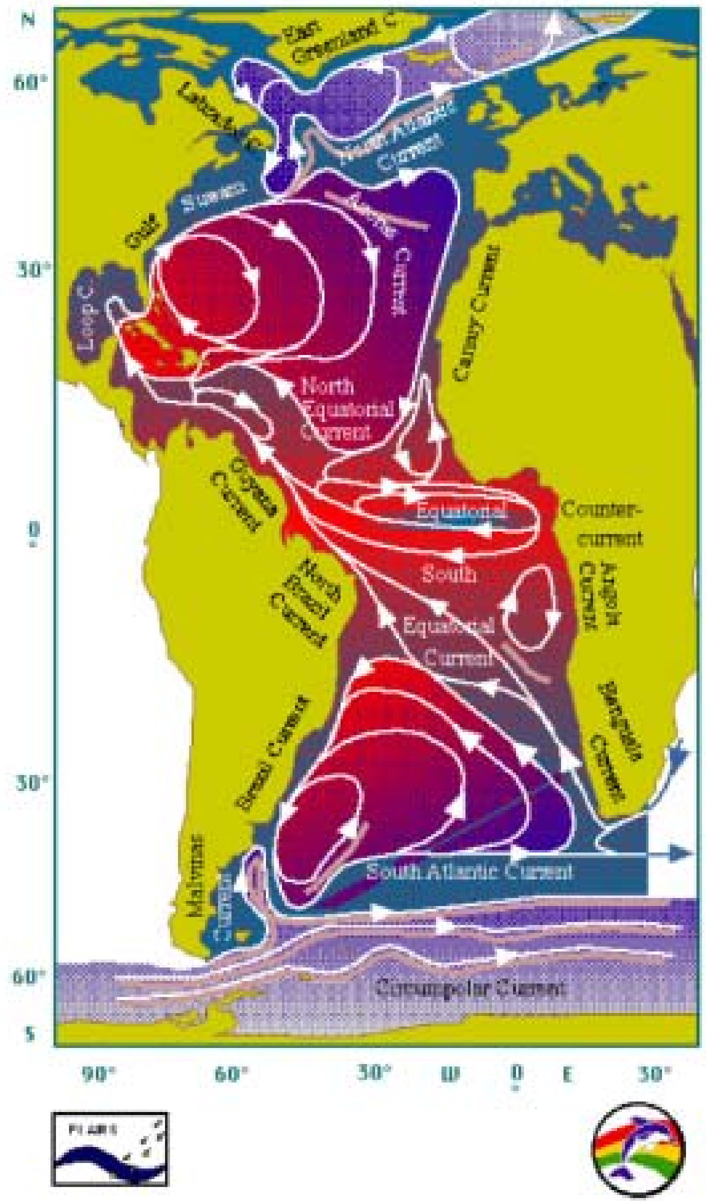
Near Surface Speed



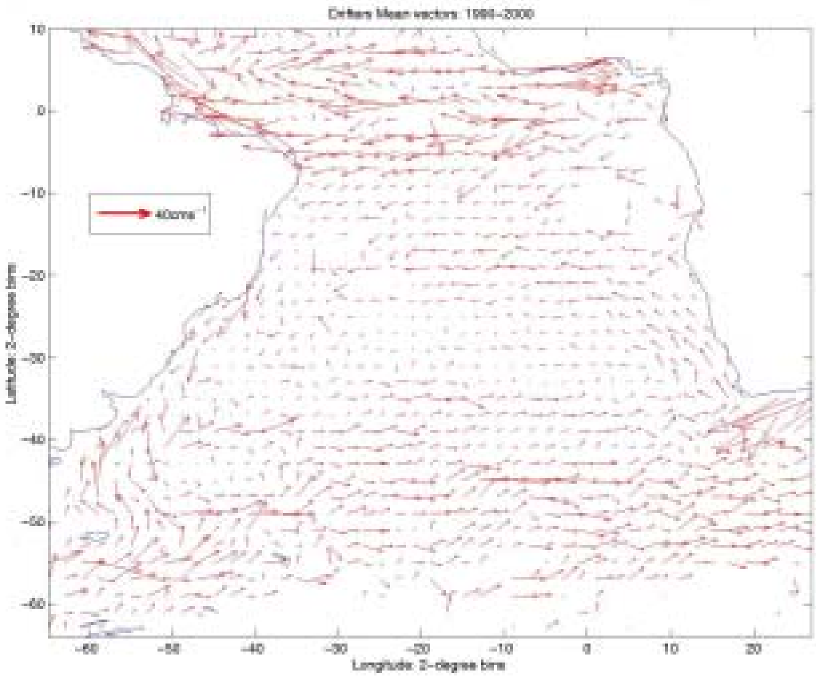
Sea Surface Height

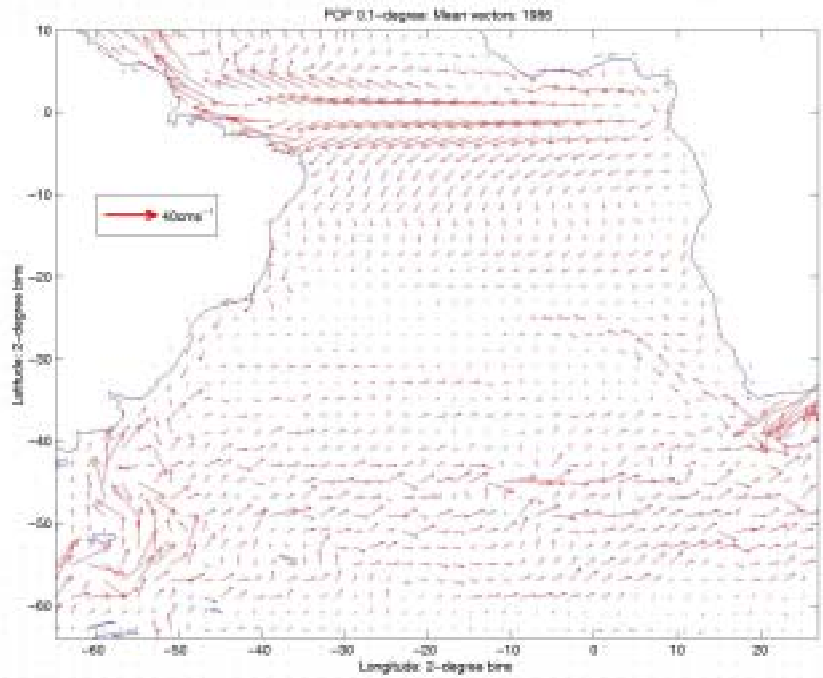


Atlantic Ocean

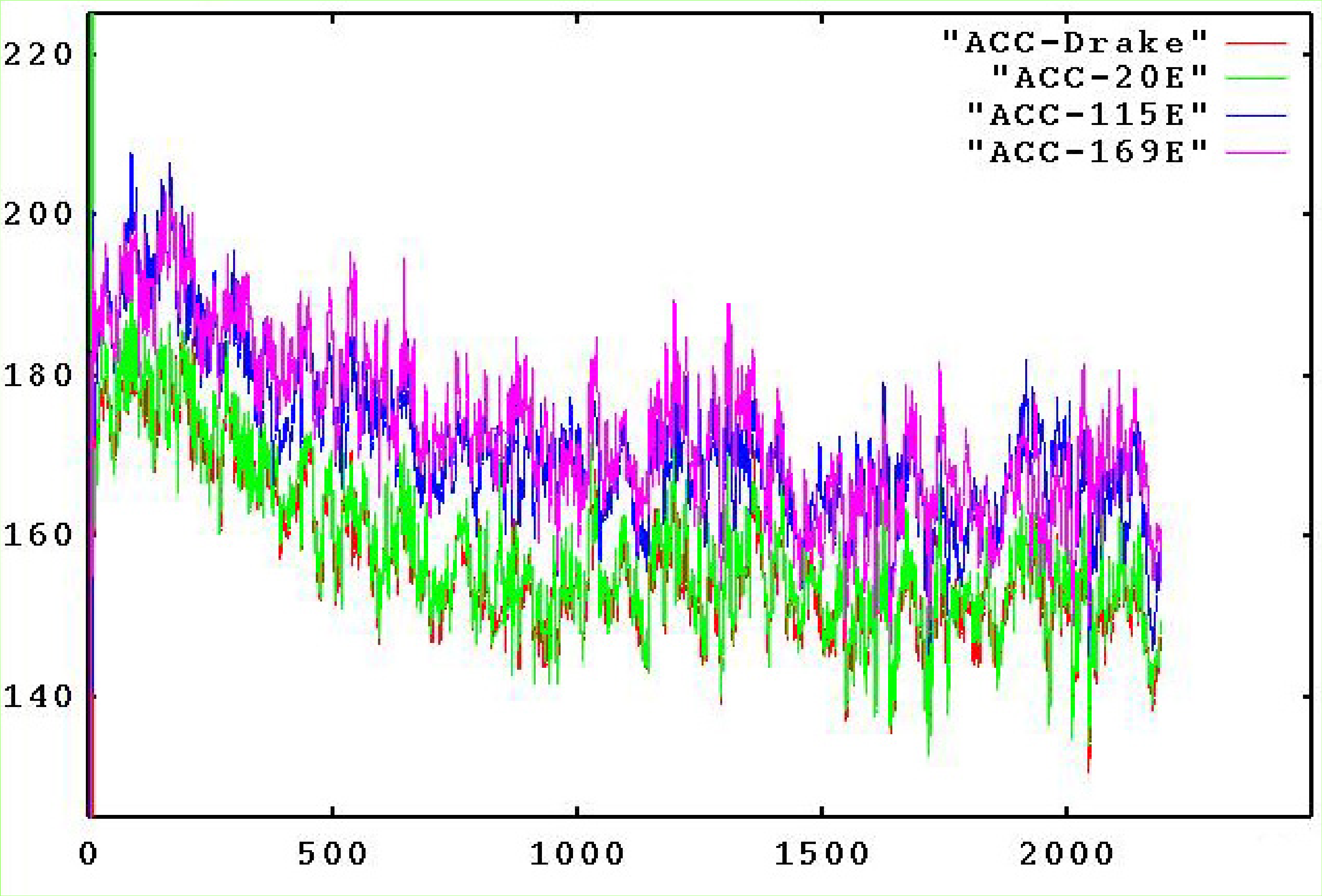


This is a colour version of Figure 14.2 of **Regional Oceanography: an Introduction** by M. Tomczak and S. J. Godfrey (Pergamon Press, New York 1994, 422 p.). See chapter 14 of the textbook for more detail on what is shown in this figure.

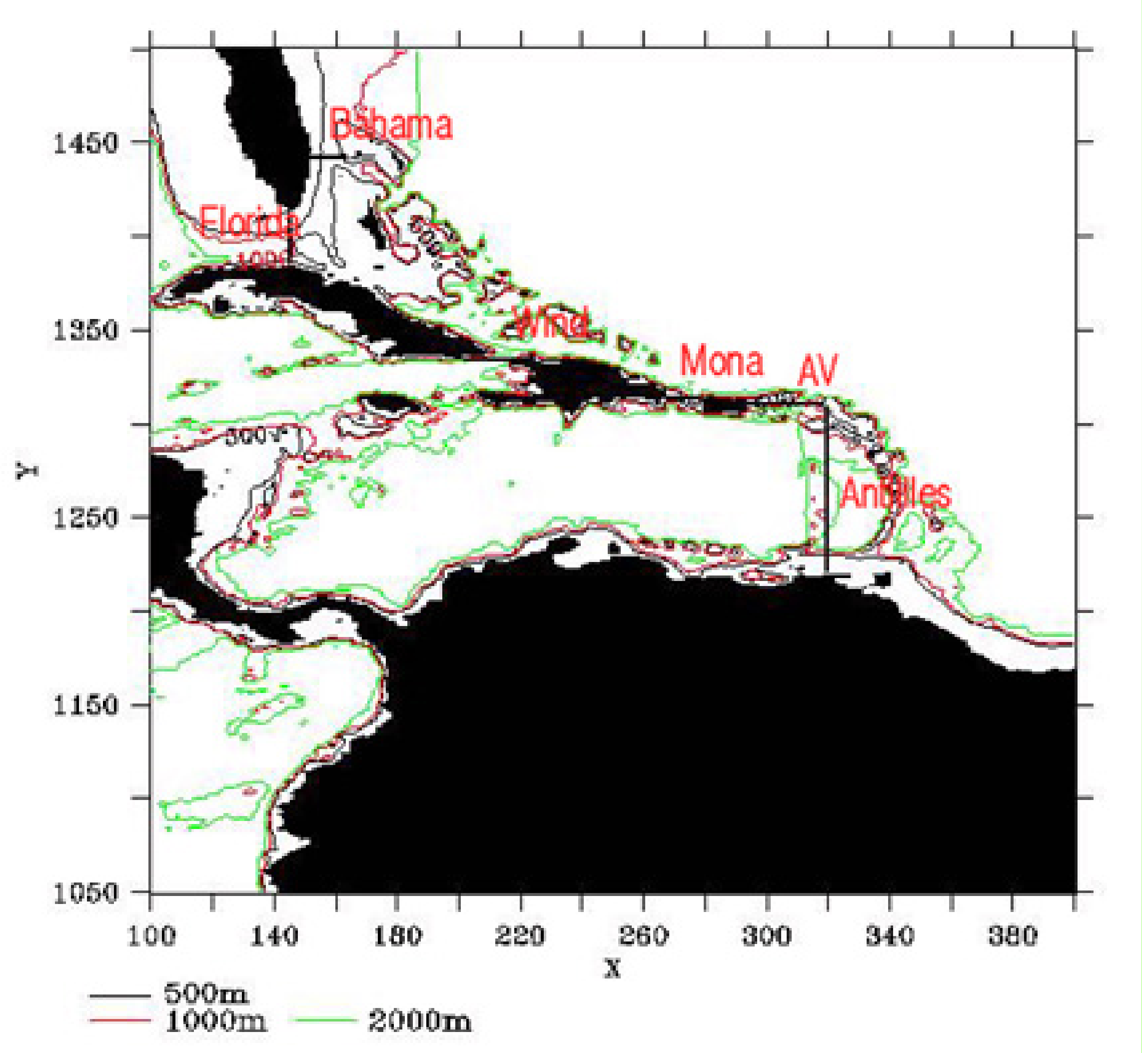

Drifters Mean vectors: 1990–2000
40cms⁻¹
Latitude: 2–degree bins
Longitude: 2–degree bins

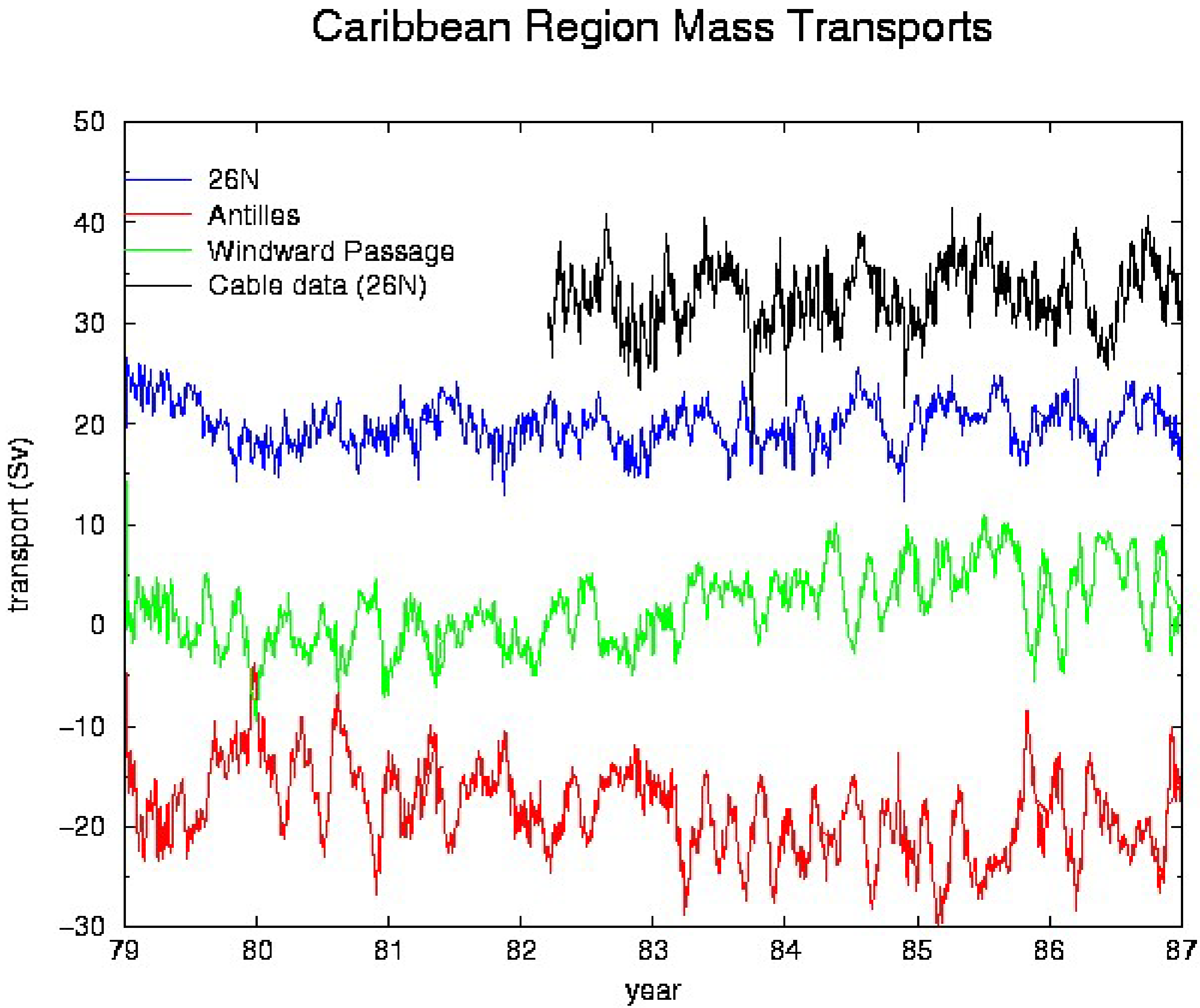

POP 0.1–degree: Mean vectors: 1986
40cms⁻¹
Latitude: 2–degree bins
Longitude: 2–degree bins

Mass Transports (Sv) in the Antarctic Circumpolar Current



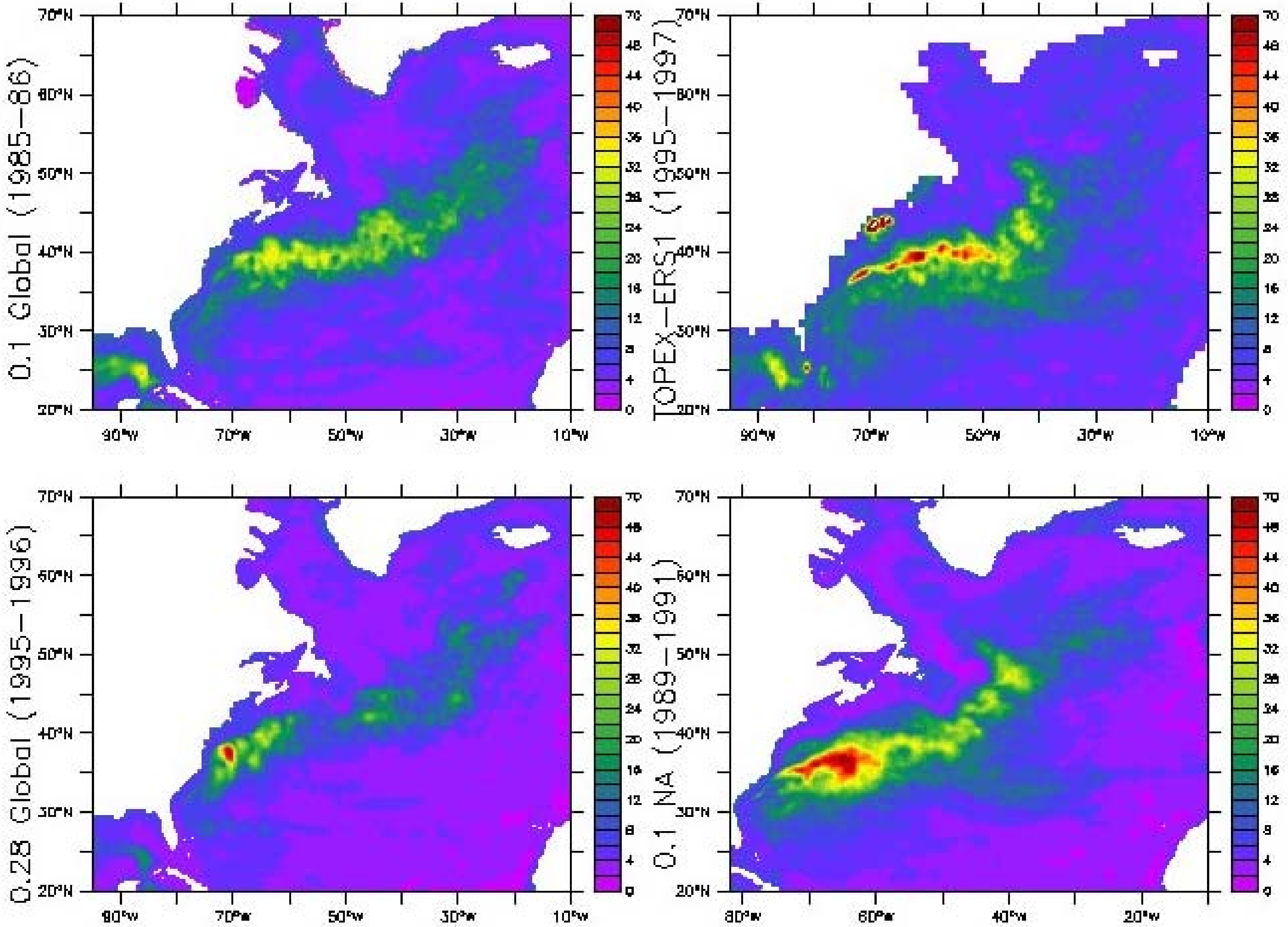
Mass Transports (Sv) through the Caribbean Sea and Florida Straits for the first 8 years of the spin-up

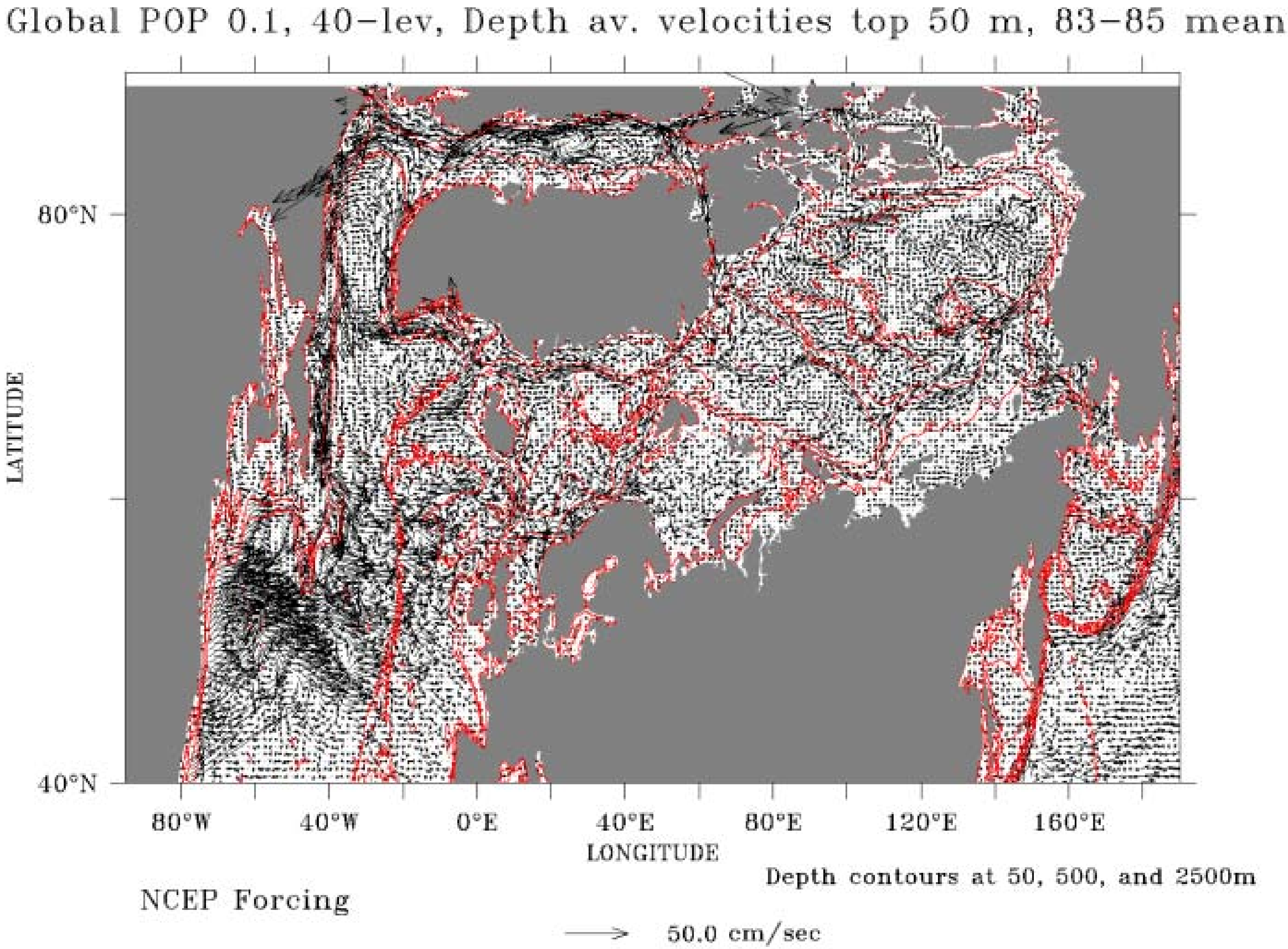


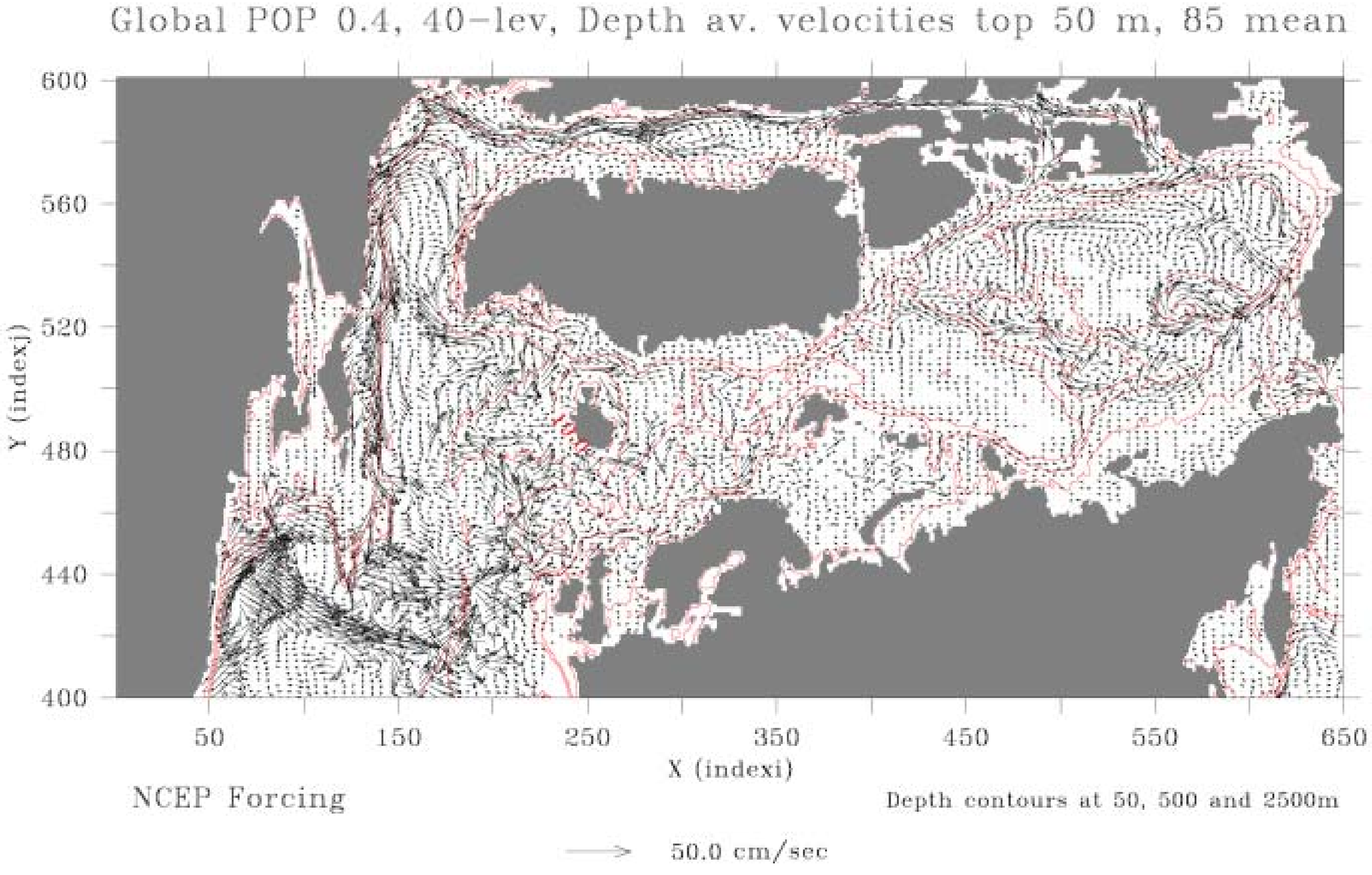


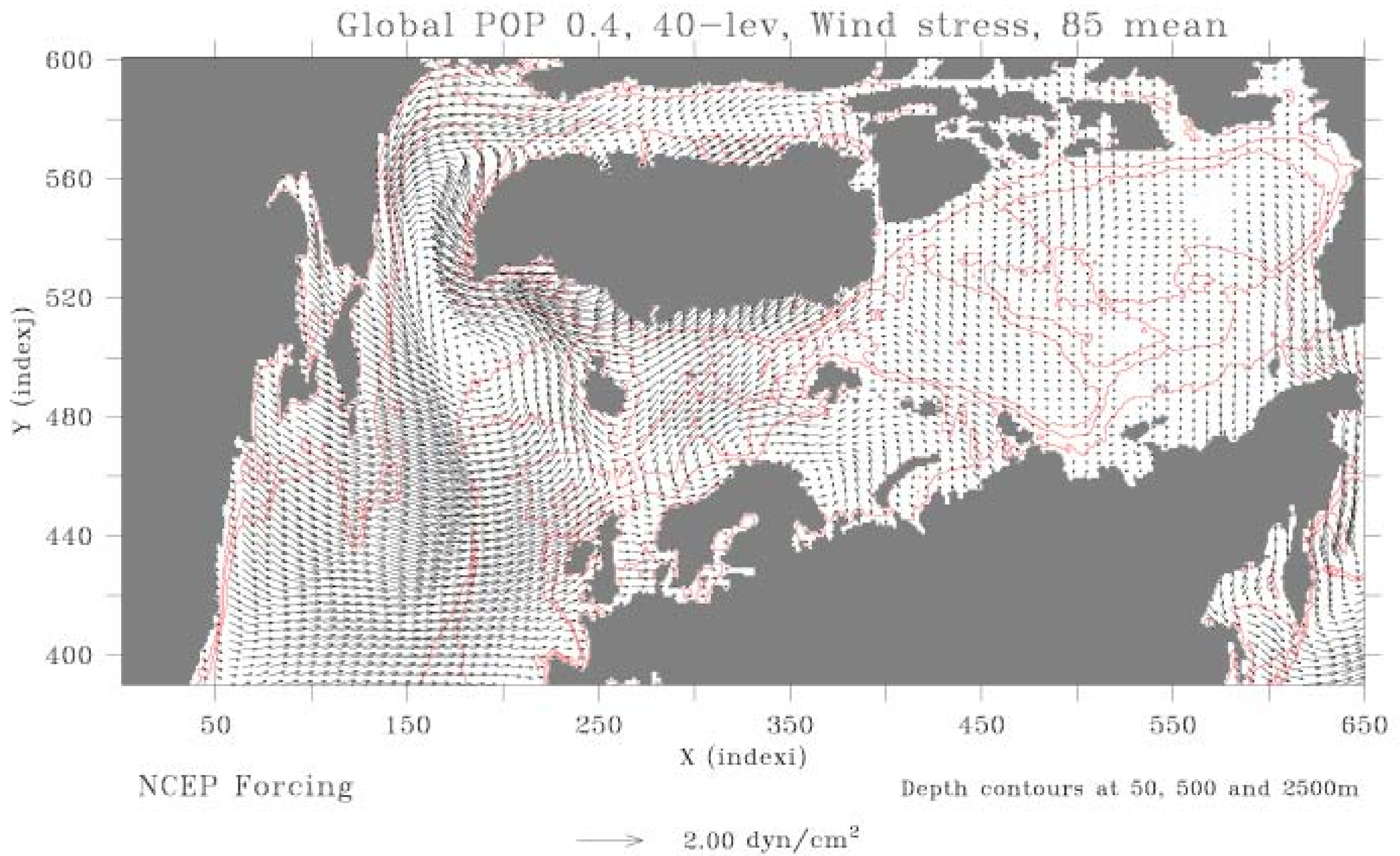
Caribbean Region Mass Transports
26N
Antilles
Windward Passage
Cable data (26N)
transport (Sv)
year
50
40
30
20
10
0
−10
−20
−30
79
80
81
82
83
84
85
86
87

Sea surface height variability (cm)

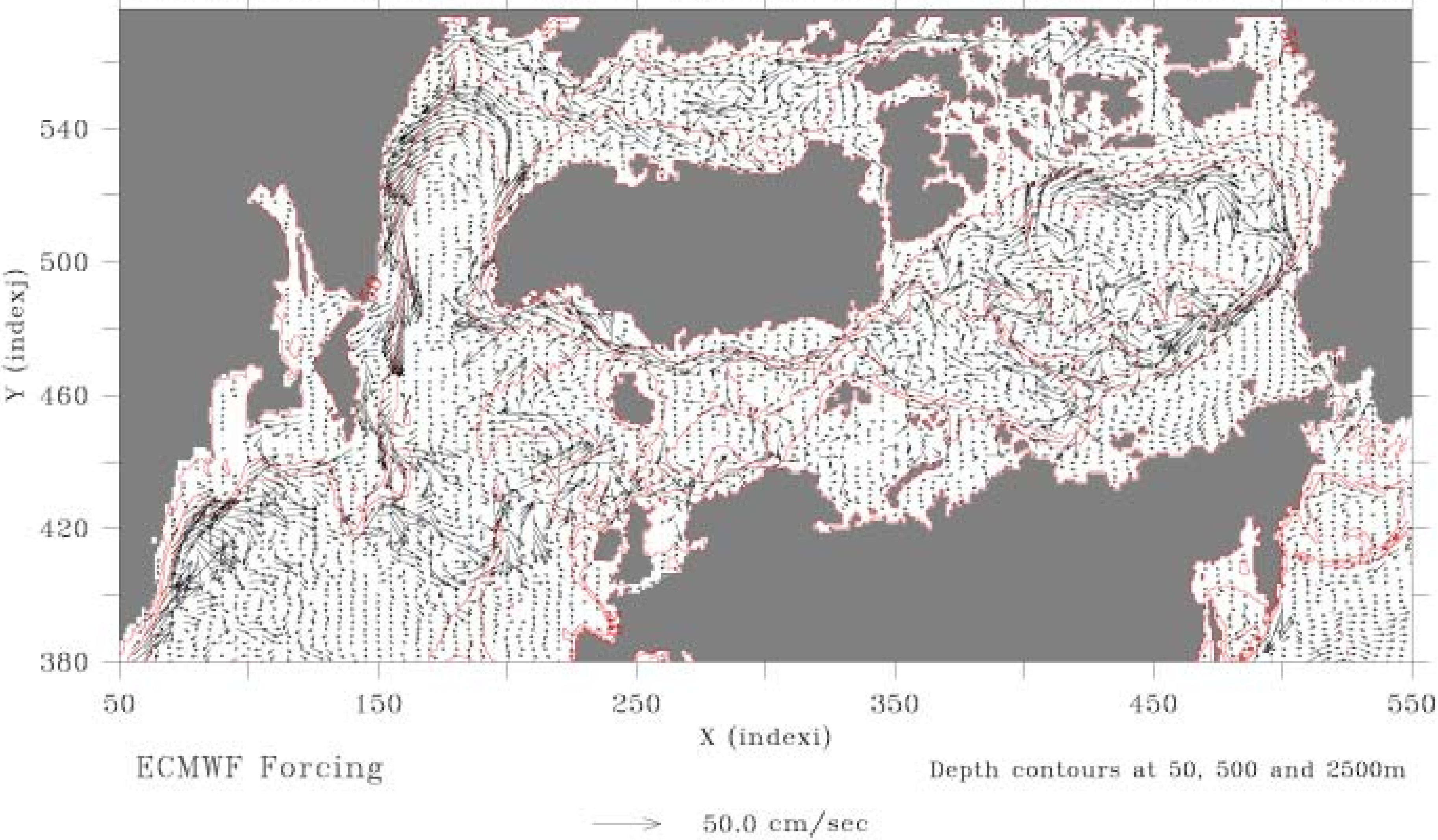


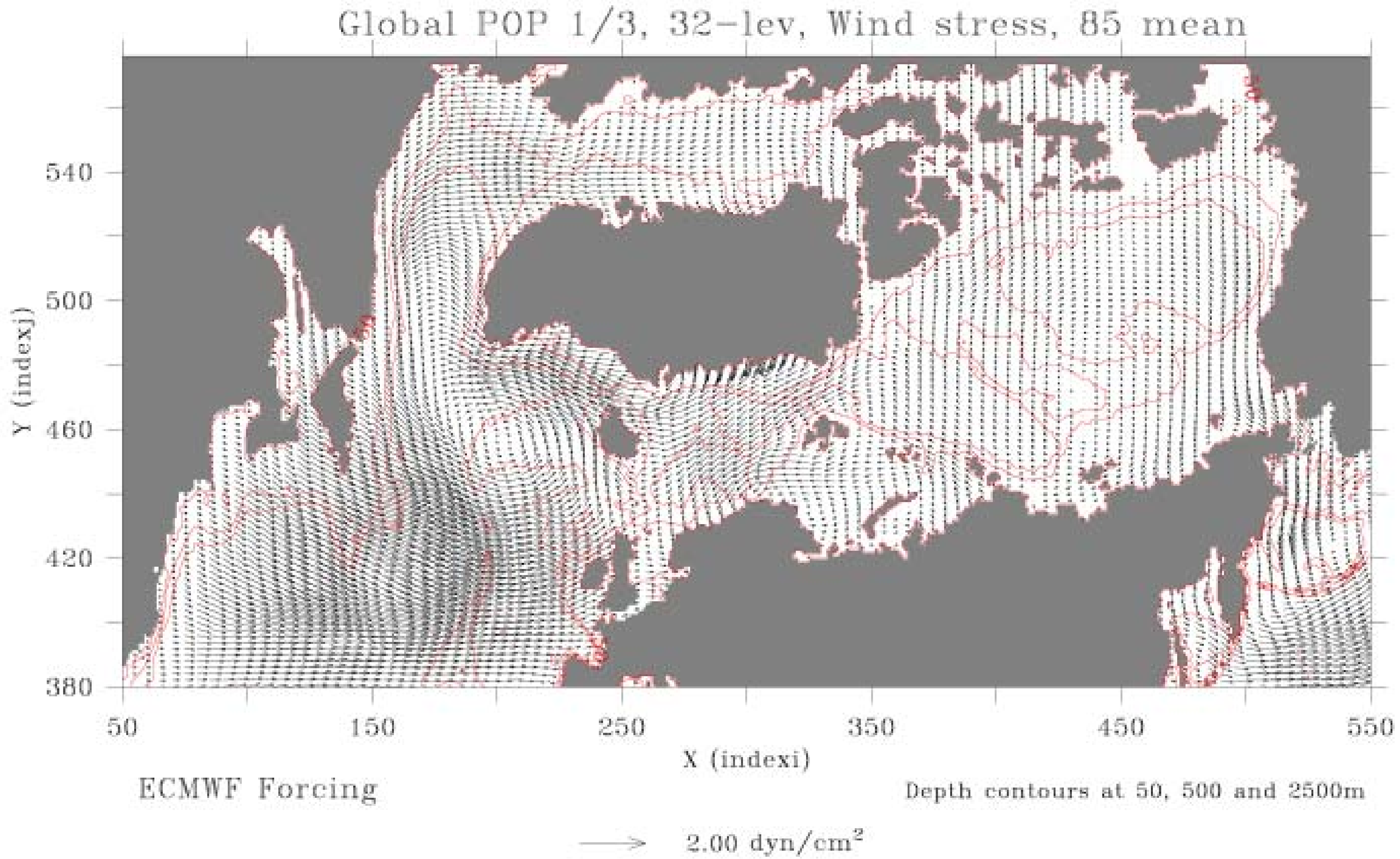

Global POP 0.1, 40-lev, Depth av. velocities top 50 m, 83-85 mean
80°N
40°N
LATITUDE
80°W
40°W
0°E
40°E
80°E
120°E
160°E
LONGITUDE
Depth contours at 50, 500, and 2500m
NCEP Forcing
50.0 cm/sec

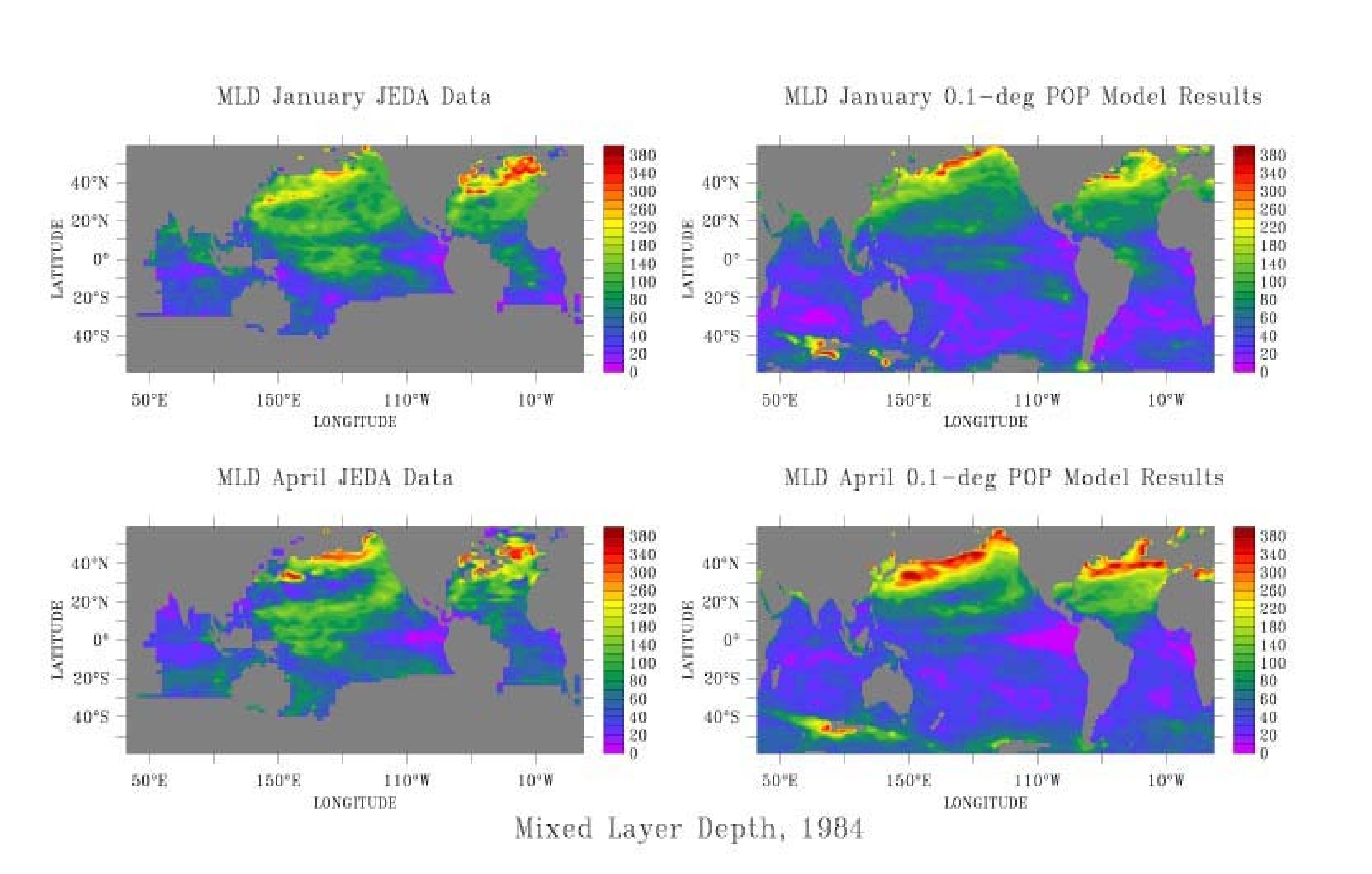

Global POP 0.4, 40-lev, Depth av. velocities top 50 m, 85 mean
600
560
520
480
440
400
Y (indexj)
50
150
250
350
450
550
650
X (indexi)
NCEP Forcing
Depth contours at 50, 500 and 2500m
50.0 cm/sec


Global POP 0.4, 40-lev, Wind stress, 85 mean
Y (indexj)
X (indexi)
NCEP Forcing
Depth contours at 50, 500 and 2500m
2.00 dyn/cm²

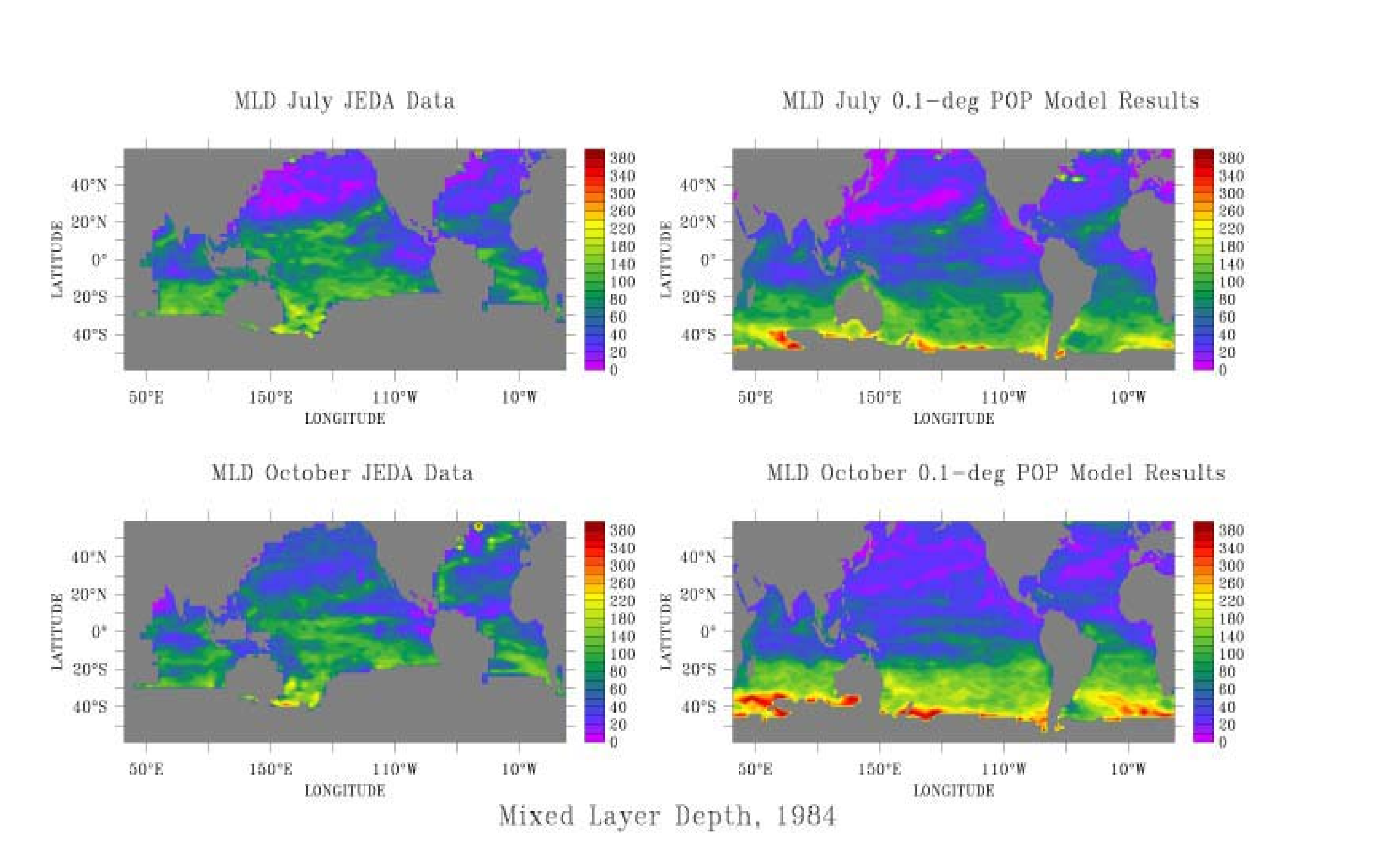
Global POP 1/3, 32-lev, Depth av. velocities top 50 m, 85 mean



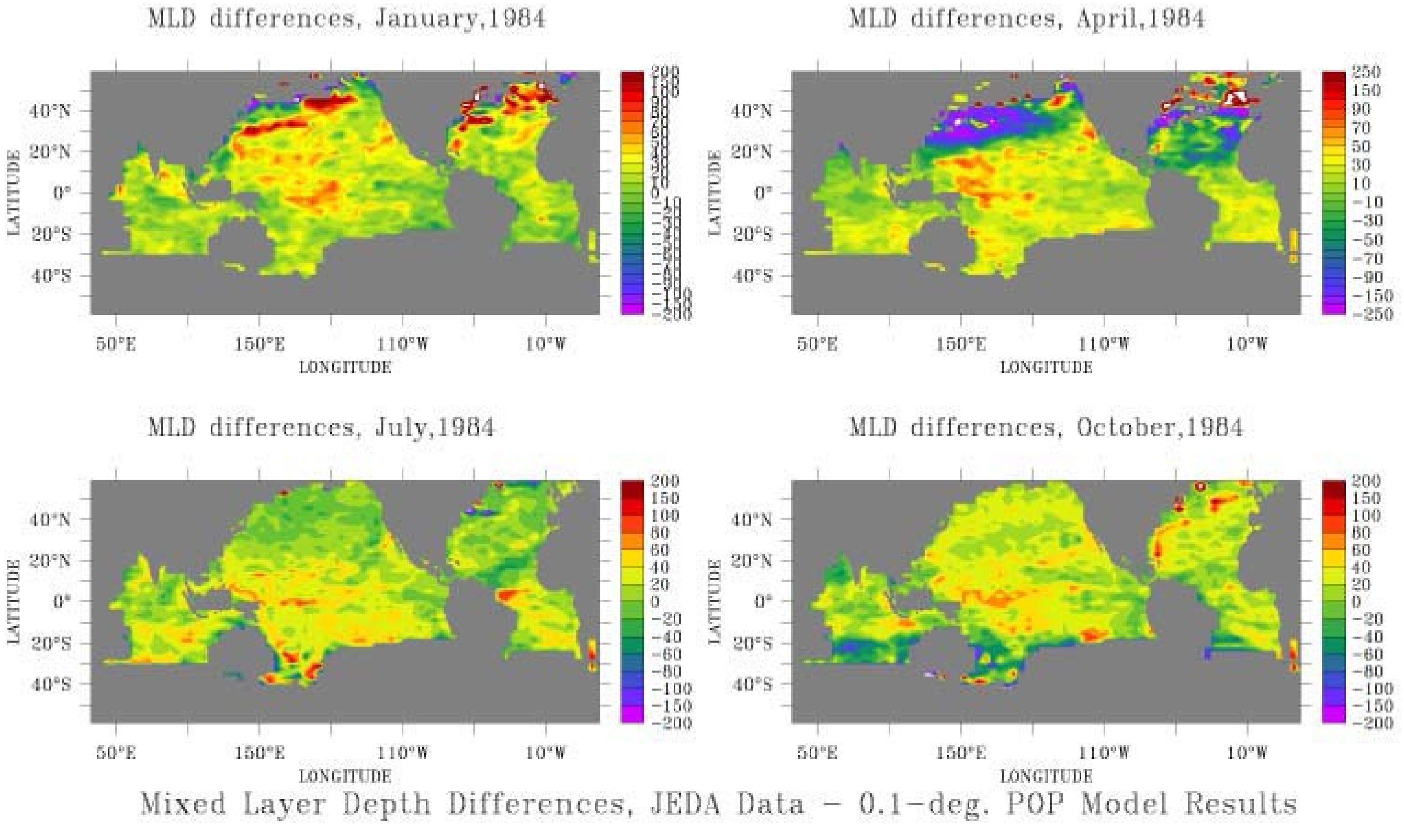

Global POP 1/3, 32-lev, Wind stress, 85 mean
540
500
460
420
380
Y (indexj)
50
150
250
350
450
550
X (indexi)
ECMWF Forcing
Depth contours at 50, 500 and 2500m
2.00 dyn/cm^2



Monthly mixed layer depth (m) from XBT data and POP for January and April of 1984. MLD is depth at which the temperature is 1 degree less than that at 5 m.



Monthly mixed layer depth (m) from XBT data and POP for July and October of 1984.

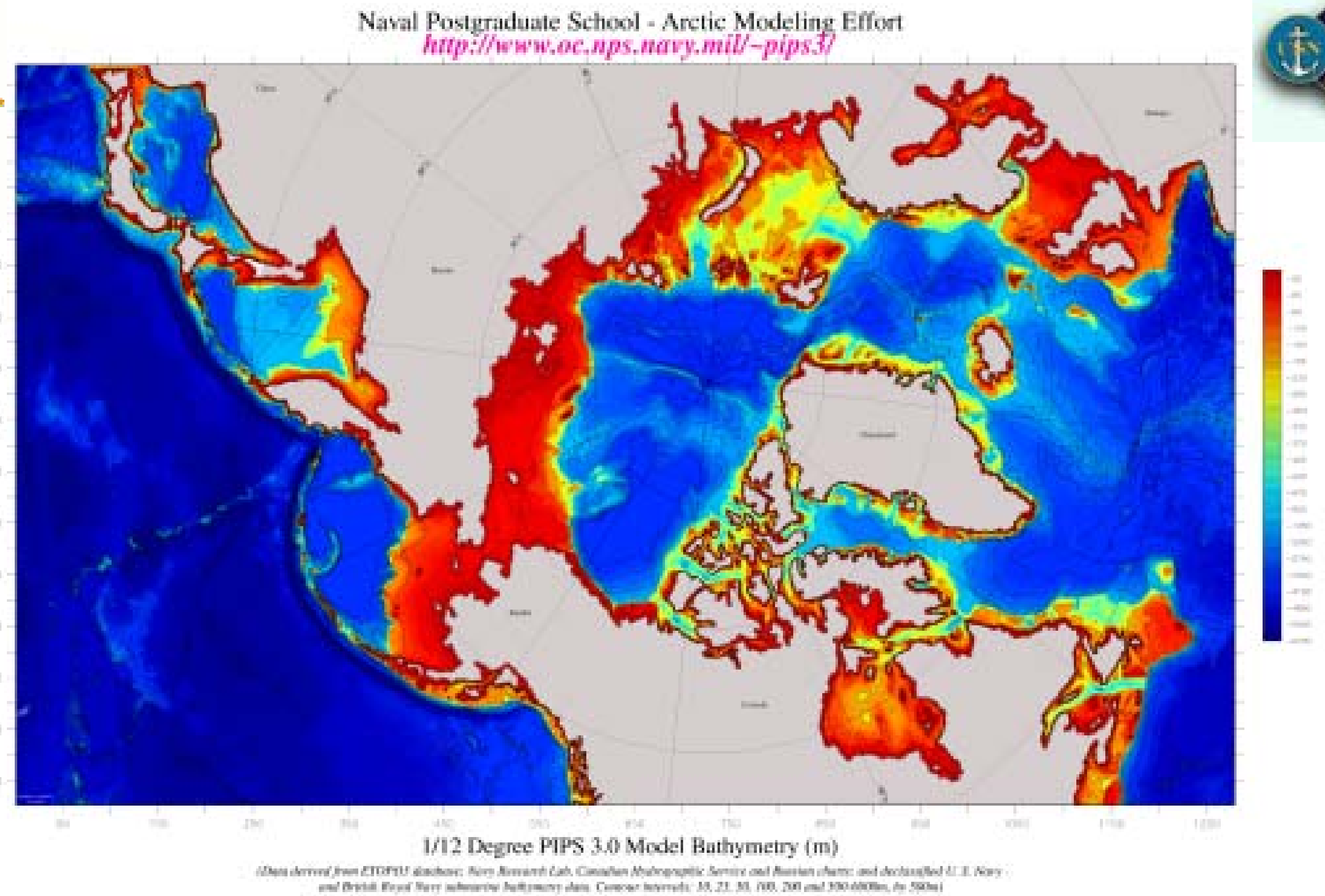


Difference in MLD between XBT data and POP for January, April, July, and October of 1984

Conclusions

- Mean surface flows are well depicted.
- Energy levels are somewhat too high in energetic flows; still too low in basin interiors.
- Kuroshio, ACC, and EAC better represented than in coarser resolution POP
- Transports are realistic.
- Gulf Stream and North Atlantic Current are poorly represented, due to set-up of polar currents.
- Mixed layers are too deep at high latitudes.

Development of PIPS 3.0



W. Maslowski,
D. Marble, W. Walczowski W., D. Stark
Naval Postgraduate School, Monterey, CA

9-km Model Results:

1. Implementation of the new IBCAO bathymetry - Model Grid: 1280x720x45

2. Implementation of the new (UW/PSC) hydrographic climatology (PHC)

3. Addition of freshwater sources from river runoff (Yukon, Mackenzie, and Russian rivers)

4. Implementation of numerical tracers for Pacific Water, Atlantic Water, and river runoff

5. Completed 60-year Integration (with 'old' sea ice model) at ARSC:
   - 27-year spinup with ECMWF-derived climatological forcing (1979-1993 mean daily-averaged annual cycle)
   - 6-year run with the repeated ECMWF 1979 annual cycle
   - 9-year run with the repeated ECMWF 1979-1981 cycle
   - 6-year run with runoff and numerical tracers with the repeated ECMWF 1979-81 cycle
   - ongoing 1979-2002 interannual simulation – 1979-1990 completed

ARCTIC REGION
SUPERCOMPUTING CENTER

9-km Model Results - Continued:

6. Development/implementation of the new sea ice model (LANL/CICE):
- energy-conserving thermodynamics with: 5 categories, 4 layers per category, snow layer, nonlinear T, S profiles (Bitz & Lipscomb, 1999)
- EVP dynamics (Hunke and Dukowicz, 1997)
- 2-D remapping scheme for horizontal ice transport (Lipscomb, 2001)
-1-D remapping scheme for updating the thickness distribution (Lipscomb and Hunke, in prep)
- stand alone and coupled versions with an interface to the NCAR CCSM flux coupler
- implementation on the global POP displaced North Pole grid
- MPI parallelism
- online documentation @ http://www.acl.lanl.gov/climate/eclare/cicecode

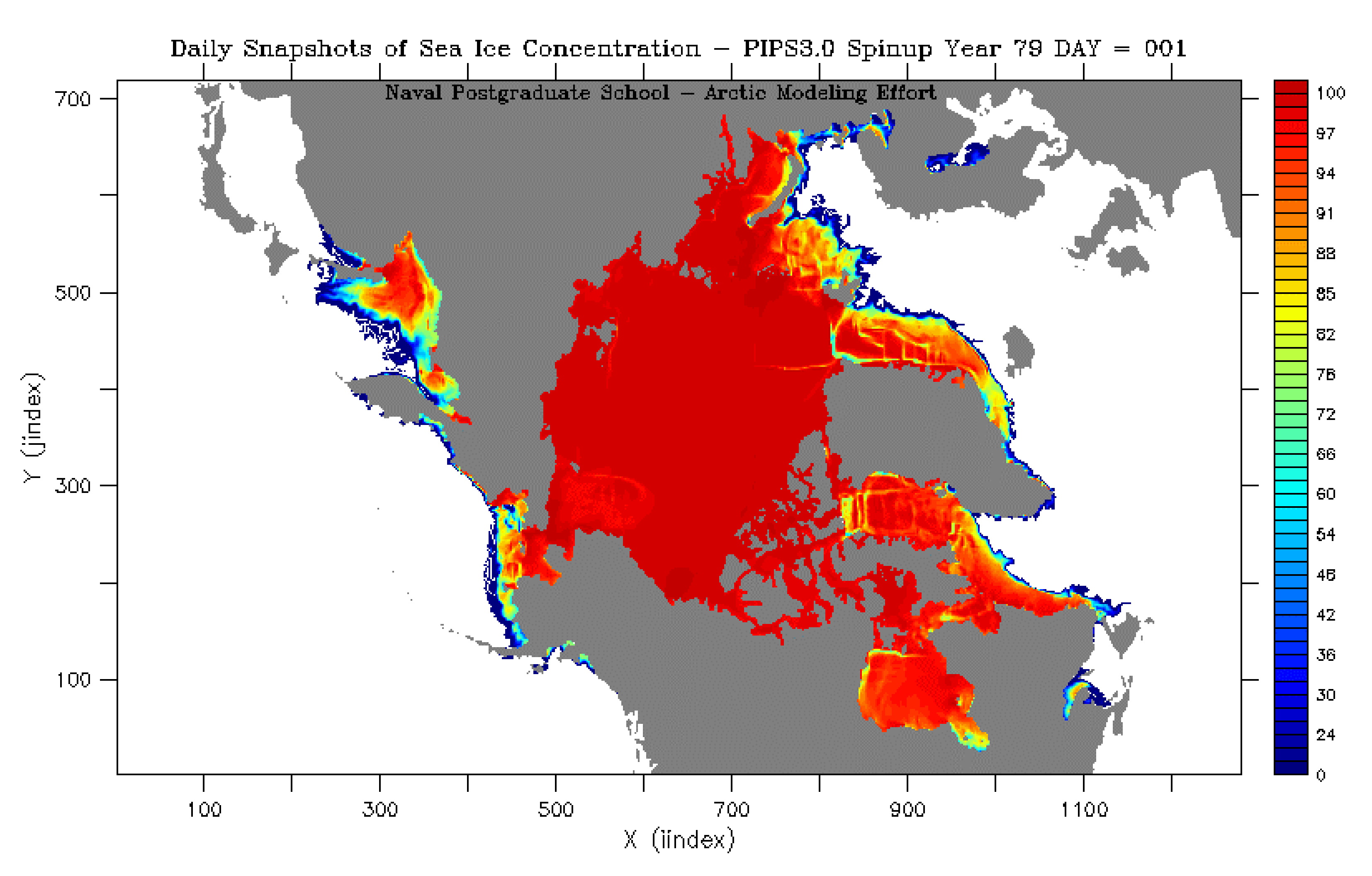
7. Completed 20-year integration (ERDC) including a 10-year spinup and the 1979-1988 interannual forcing run forced with ECMWF data
8. Coupling of the new sea ice model to the ocean model – ongoing
9. Assimilation of SMM/I-derived sea ice drift data using Optimal Interpolation (OI)

Stand alone model parallelization (ERDC-O3K):

#CPU	#TS Time:	total (sec)	EVP (sec)	#sec/ts	time/3days (minutes)	time/5days (minutes)
4	300	21887	9834	73	109.5	182.5
8	90	3378	1661	37.5	56.3	93.8
16	90	2109	1186	23.43	35.15	58.6
32	90	1439	904	16	24.0	40.0 ←
64	90	741	449	8.23	12.35	20.6
128	90	418	214	4.65	6.98	11.62
256	1200	2470	1467	2.06	3.09	5.15

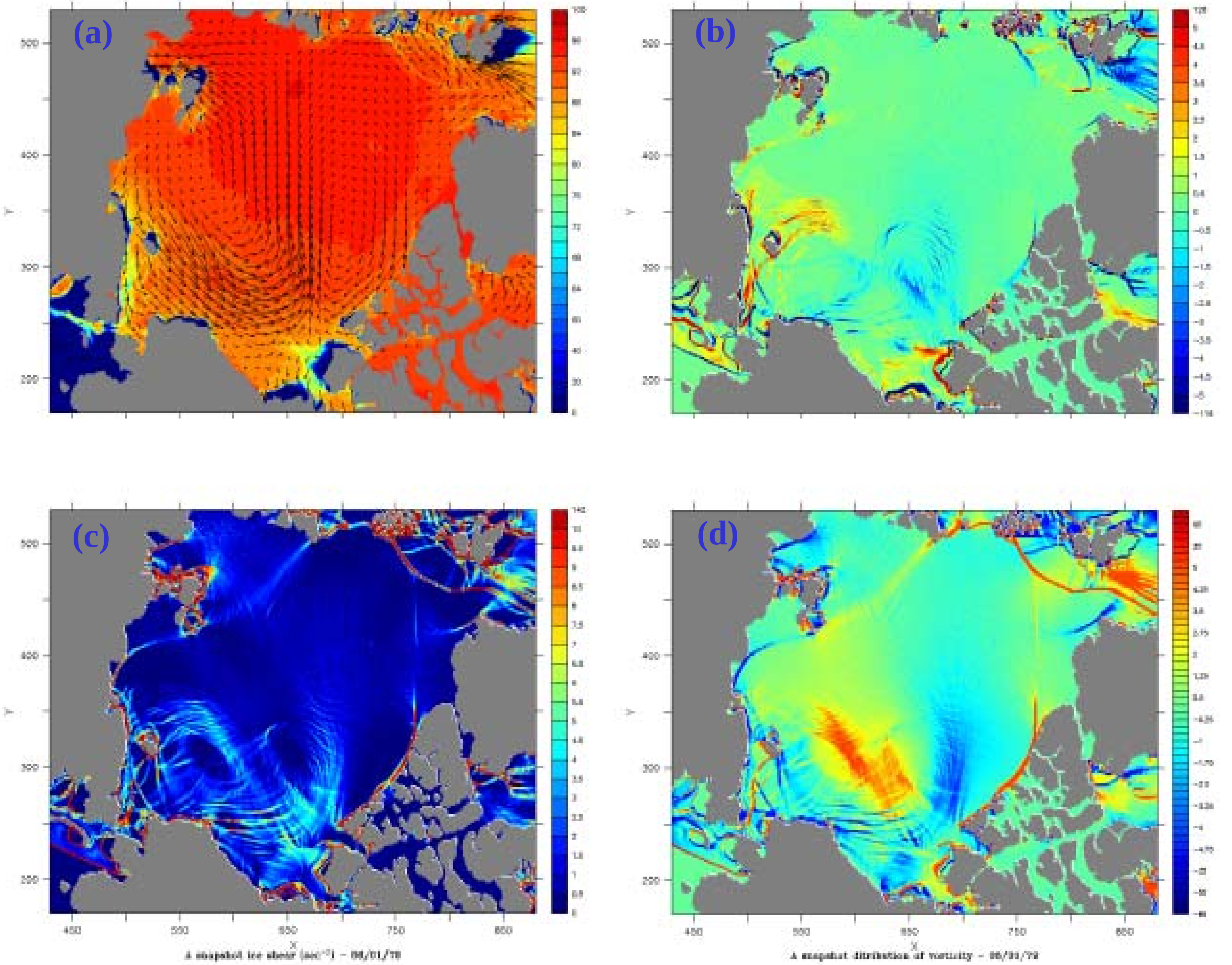
Array(1280x720); 5 ice categories, 4 layers per category; timestep = 2880 sec; daily-mean constant forcing

Results from the 9-km (NPS) coupled ice-ocean model (with 'old' sea ice model)

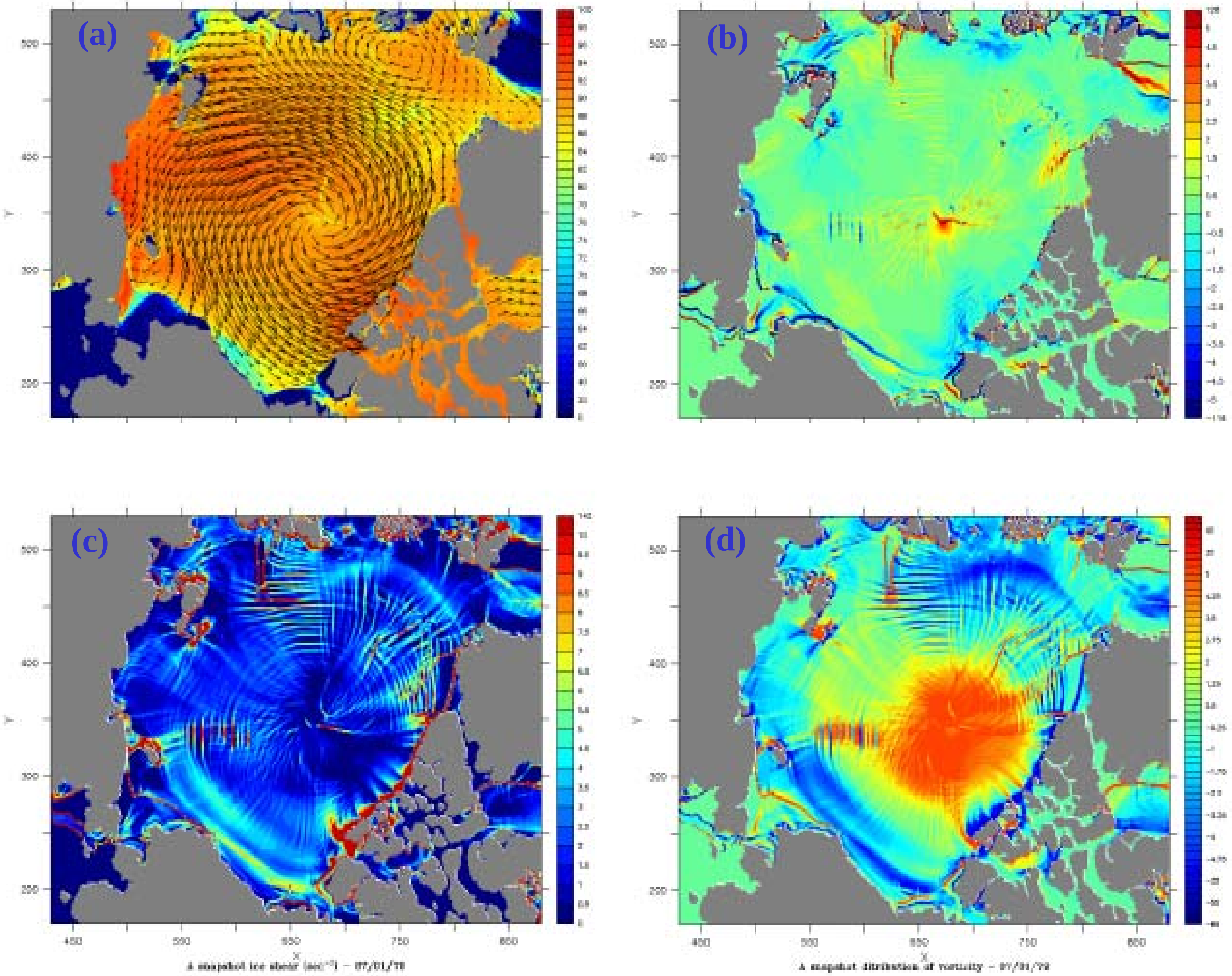


Daily snapshots of sea ice concentration (%) – 1979-1981

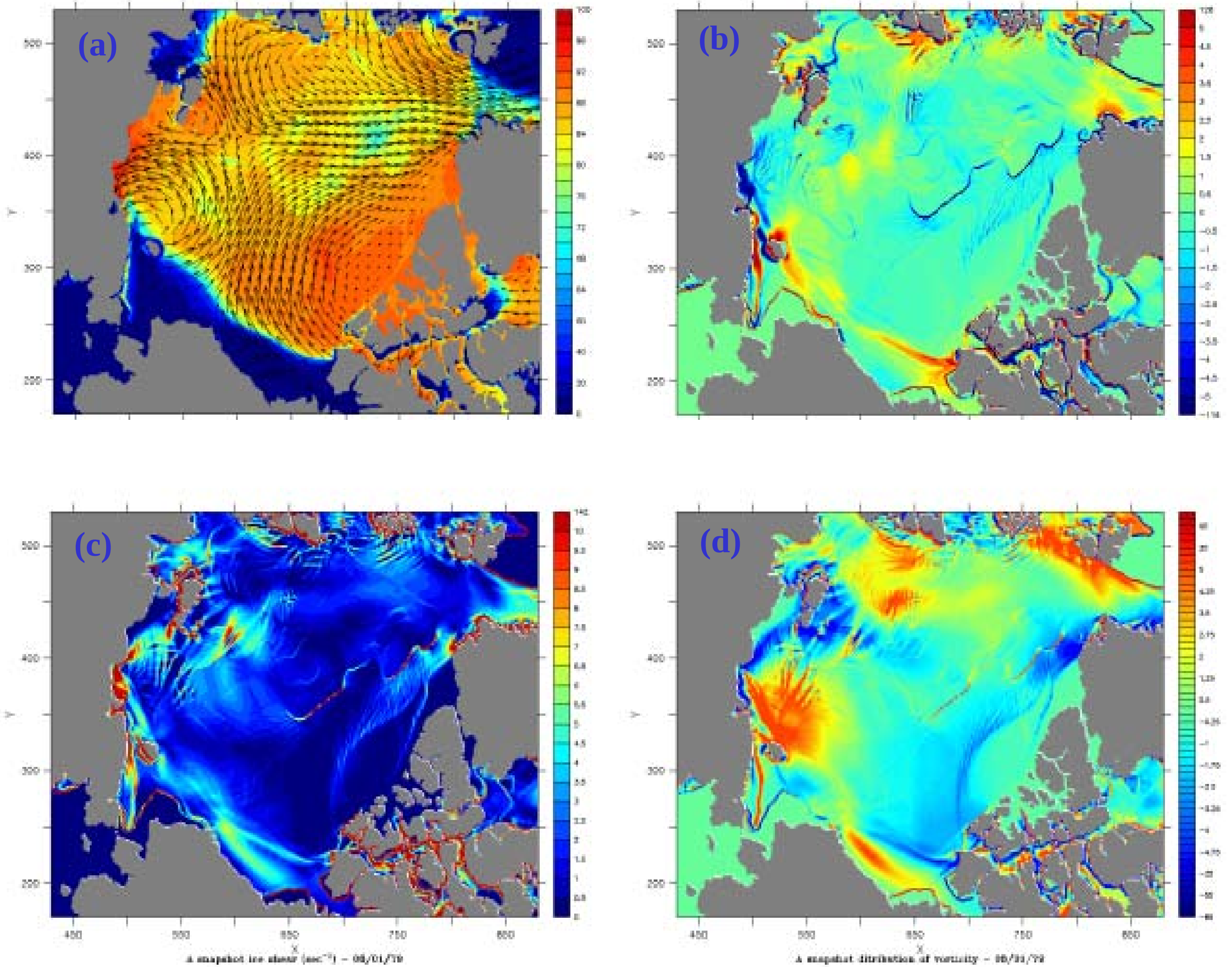
A snapshot of (a) ice area and drift, (b) divergence, (c) shear, and (d) vorticity- Spinup 06/01/79



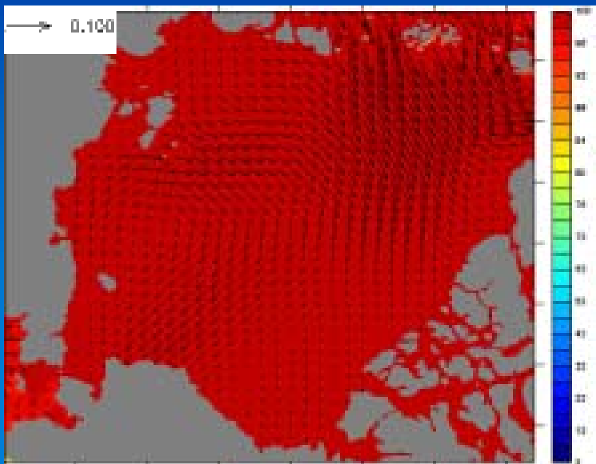
A snapshot of (a) ice area and drift, (b) divergence, (c) shear, and (d) vorticity- Spinup 07/01/79



A snapshot of (a) ice area and drift, (b) divergence, (c) shear, and (d) vorticity- Spinup 08/01/79

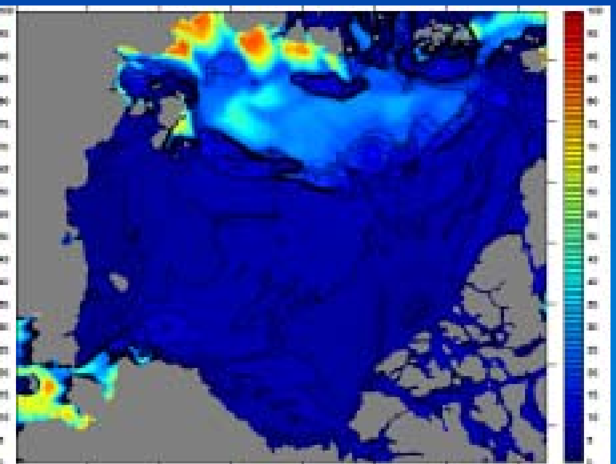


Multi-category Total and Fractional Sea Ice Concentrations (%) – April 1, 1982

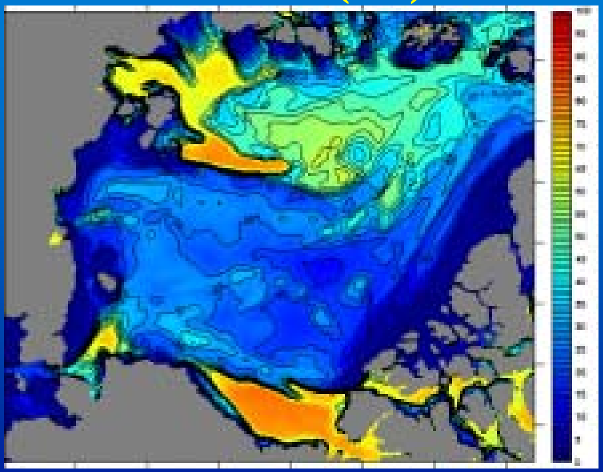


Total Ice Concentration (%)
and Drfit (m/s)

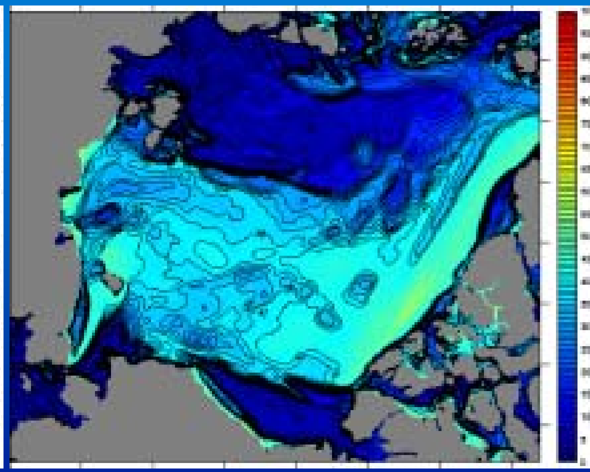
Category I (0-0.45 m)



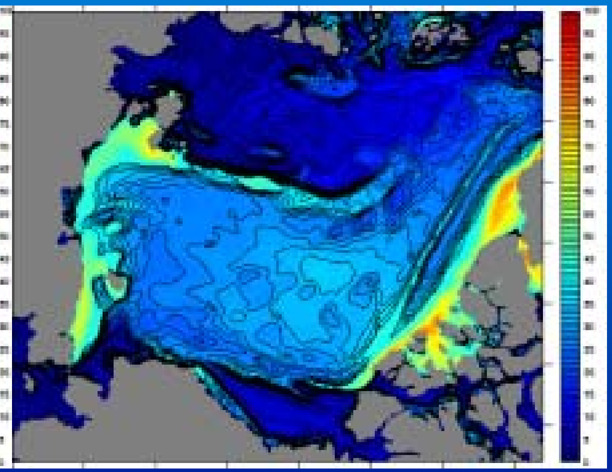
Category II (0.45-1.2m)



Category III (1.2-2.2 m)

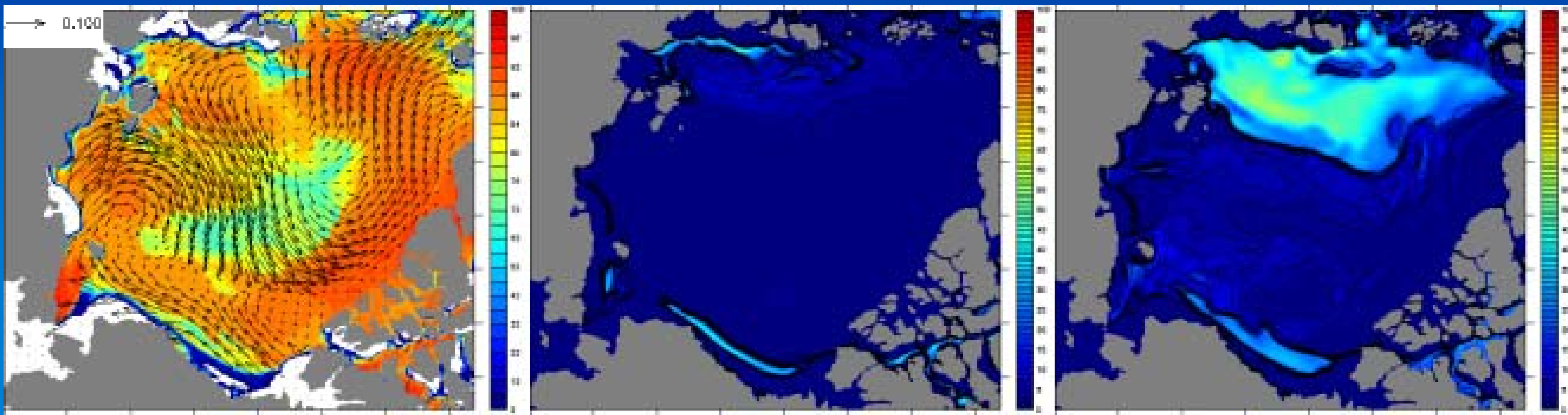


Category IV (2.2-4.5 m)



Category V (4.5-9.0 m)

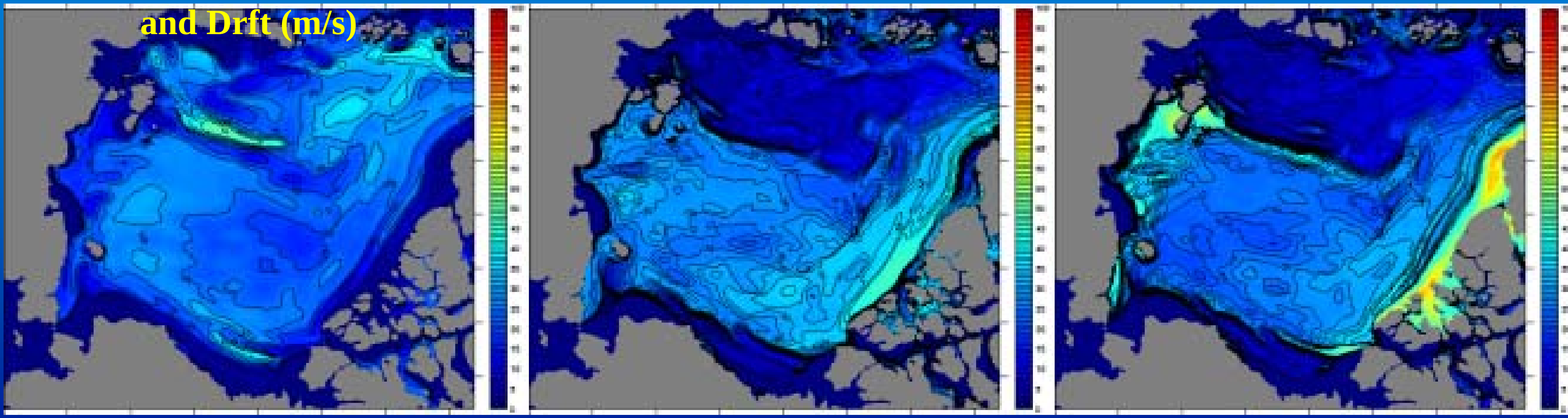
Multi-category Total and Fractional Sea Ice Concentrations (%) – September 1, 1982



Total Ice Concentration (%)
and Drft (m/s)

Category I (0-0.45 m)

Category II (0.45-1.2m)



Category III (1.2-2.2 m)

Category IV (2.2-4.5 m)

Category V (4.5-9.0 m)

An improved skill in modeling the evolution of first- and multi-year ice

Conclusions:

- A regional/nested approach might be useful for realistic representation of the Arctic sea ice and ocean processes in global operational and climate models

- A regional Arctic climate model (at sufficiently high resolution) should provide predictive capability for the region at seasonal to interannual scales

- Ensemble simulations of several arctic change scenarios (e.g. warming, cooling, no change) could provide the Navy with critical predictions of possible environmental trends currently defined based on ‘short/biased’ data sets